Section 4

Water Quality Impacts

To estimate the change in water quality that is expected to take place
under the various options for reducing pollutant loadings it is necessary to
take into account the change in loadings, the dispersion pattern in the
Harbor from the point of discharge to the areas where recreation and fishing
take place (receptor areas), and the current ambient water quality in these
areas. The reception areas defined for the purposes of this study are shown
in Figure 4-1. Pollutant loadings continue under all treatment options but
at rates less than the current ones. Thus, percent improvements in water
quality are related to percent reductions in pollutant loadings under the
various options. The changes experienced under any of the options are not
expected to be in the form of new dispersion patterns but rather are expected
to be concentration reductions in the water column. The changes are
incremental ones, evaluated in relation to current loadings and current
ambient quality.

4.1 Water Quality Impacts of STP Dischargers

To assess the impact of STP discharges in Boston Harbor it is important
to know how such discharges are dispersed throughout the Harbor. Since
discharges to the Harbor are subject to diverse and variable conditions, the
water quality throughout the Harbor is not uniform. A few models have been
developed to quantitatively explain some of these variations and to correlate

Figure 4-1.   Receptor Areas for the Boston Harbor Study
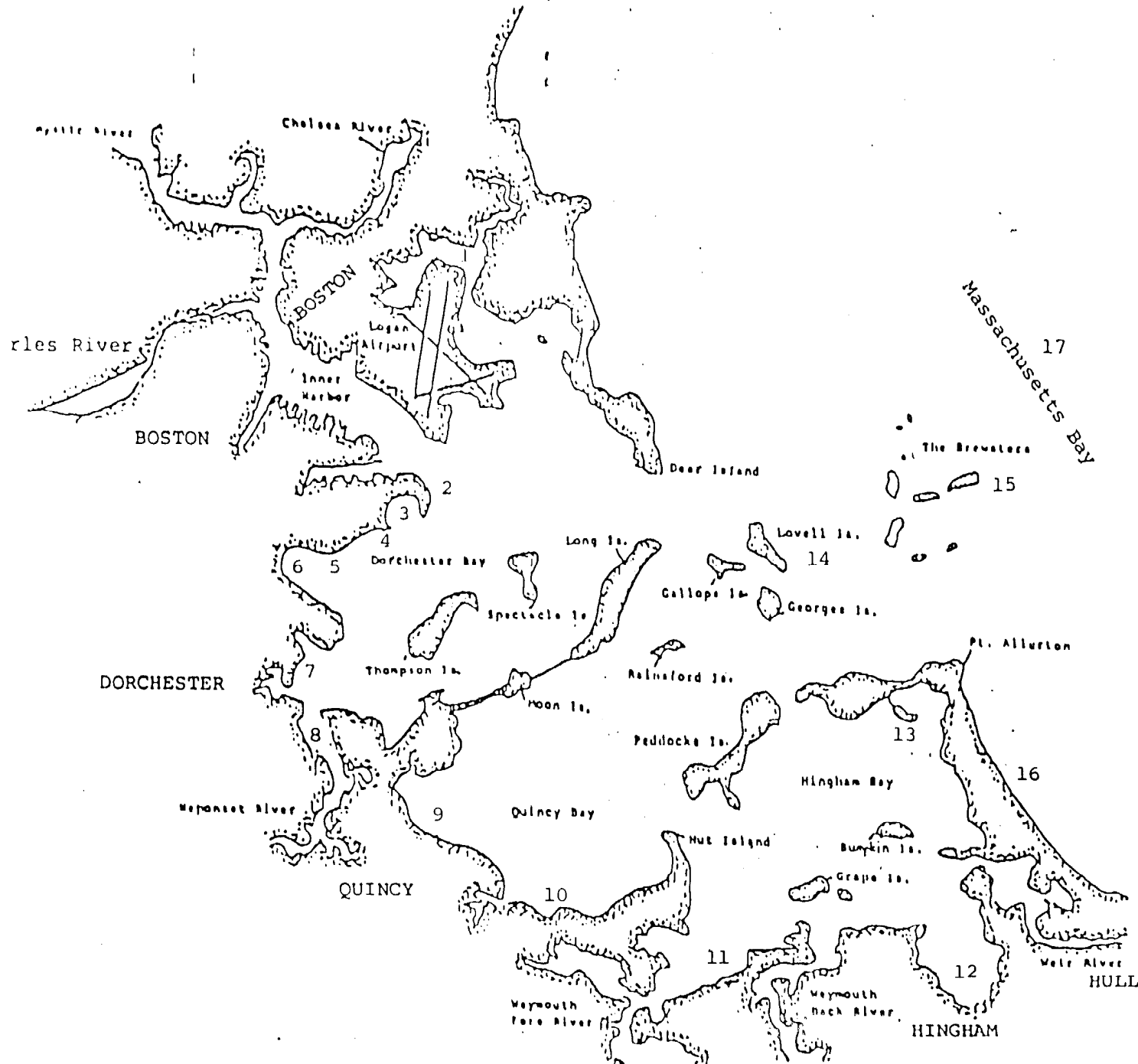
1. Constitution Beach
2. Castle Island
3. Pleasure Bay
4. City Point
5. L&M Streets Beach
6. Carson Beach
7. Malibu Beach
8. Tenean Beach
9. Wollaston Beach
10. Quincy Town Beaches
11. Weymouth Bay
12. Hingham Harbor
13. Hull Bay
14. Outer Harbor Islands
15. Brewsters Islands
16. Nantasket Beach
17. Massachusetts Bay

STP discharges with water quality. The DISPER model, developed at Massachu-

setts Institute of Technology, was designed specifically to quantify the

dispersion of STP discharges into Boston Harbor. This model was used in the

assessment of a deep ocean outfall in the MDC's application for a waiver to

secondary treatment (Metcalf and Eddy, 1979). We use the dilution ratio

results to predict relative changes in water quality but use ambient water

quality data from other sources.

The DISPER model (and the associated CAFE model) relies largely on water

movement (currents) to describe dispersion.[a] It models BOD only and

predicts volumetric inflows and outflows from the Harbor. Whether pollutant

loadings move exactly as does the water is unknown because settlement and

decomposition in transport, propensities of marine organisms to assimilate

wastes, etc., are not precisely understood. Assumptions regarding settling

rates, decay rates, biological uptake , and chemical reactions are employed in

running DISPER.   This model is useful in comparing relative dispersion

differences for the different STP options while precise, absolute values

predicted by DISPER may not be as reliable. It was with this in mind that

the maps of dilution ratios in Section 2 were developed based on the DISPER

model (Figures 2-4, 2-5, and 2-6).

In order to use the dilution ratios produced by DISPER to assess water

quality impacts, current water quality must be known. The Boston Regional

Office of the Environmental Protection Agency (Region I) has recently

undertaken to bring together all water quality sampling data collected in the

Harbor since 1968. They have stored the data in a computer system called the

---

[a] See Appendix A.2 for a further description of this model.

Boston Harbor Data Management System and, in December 1983, could produce

computer-generated maps with statistically-averaged data for various points

throughout the Harbor and adjacent waters. The information from this system

that we used in the analysis below includes data on fecal coliform, BOD_5,

and total suspended solids averaged over the years 1968 to 1983 at the

receptor sites of interest to this study.

To calculate the water quality impacts of reduced pollutant loadings

under the various STP options, the change in effluent concentrations were

multiplied by the dilution ratios at the various receptor sites (Table 4-1).

The reduction was compared to current ambient quality to calculate a

percentage change in water quality. This simplified approach is clearly not

accurate if absolute values for water quality are desired. The nature of

both the current water quality data and the limitations of the dispersion

model preclude any attempt to predict absolute values. However, for the

purposes of our analysis percentage changes in water quality with a range to

indicate the degree of uncertainty is sufficient.

4.2 Water Quality Impacts of Combined Sewer Overflows

The individual contractor reports on combined sewer overflows included

modeling for water quality impacts. In those reports the impact was

evaluated using both statistical and time-varying models. The statistical

modeling was used to produce a long-term picture of the quality of water in

different segments of the harbor. The time-variable model produced dynamic

changes in water quality over a finite period of time in order to predict the

results of discrete storm events. Total coliform counts were used in both

Table 4-1.   Effluent Concentrations and Dilution Ratios
Used in the Water Quality Impact Analysis

EFFLUENT CONCENTRATIONS [a]

| Pollutant | Existing Facilities | | Deep Ocean Outfall Option | Secondary Treatment Option |
	Deer Island	Nut Island		
Fecal Coliform (MPN/100 ml)	1500	1500	1500	1500
BOD_5 (mg/1)	127.6	105	115	30
TSS (mg/1)	121	110	86	30

[a] Values as summarized in EPA (1983) and Metcalf & Eddy (1979).

[b] Includes sludge discharged into Presidents Roads.

DILUTION RATIOS [c]

| Receptor Area | Outfall Location | | |
	Presidents Roads (Deer Island)	Nantasket Roads (Nut Island)	Ocean Outfall
Constitution Beach	500	---	---
Dorchester Bay	100-200	---	---
Quincy Bay	---	50-100	---
Hingham Bay	---	100-200	---
Cuter Harbor Islands	50	50	---
Brewsters Islands	500	500	200
Nantasket Beach	---	500	200
Massachusetts Bay	1000	1000	200

[c] From DISPER contour maps.

the statistical and time-variable models. Although the models predict actual

total coliform counts for both existing conditions and under the recommended

plan, we state the results in terms of relative percentage changes both to

indicate the degree of uncertainty and as sufficient for our purposes.

The studies of the Quincy sewer systems did not model water quality. In

this study we have assumed the situation to be similar to the Dorchester Bay

area in this regard.

4.3   Estimated Water Quality Impacts of the STP and CSO Treatment Options

Table 4-2 presents the results of the water quality impact analyses. The

entries are ranges of predicted percentage change in water quality due to

each treatment option at each receptor site.   Table 4-3 presents best-guess

point estimates for the same options and receptor sites.   (Appendix A gives

details for these calculations.)   These were compiled for use in several of

the benefit estimation approaches. Again it should be noted that limitations

of both data and methodology preclude estimation of absolute changes in water

quality.   However, relative percentage changes are adequate for the benefit

estimation procedures to be used in the remaining sections of this report.

This report investigates pollution due to sewage treatment plant

discharges and combined sewer overflows. Other point and non-point sources

exist which were not included in the scope of this report. They include the

large amount of shipping and boating in the Harbor, run-off from urban areas

not collected by the sewer system and potential resuspension of pollutants

from sediments in the Harbor. Thus, our estimates of water quality changes

do not reflect complete reduction of pollutant levels because of these other

sources whose impact is, essentially, unknown at this time.

Table 4-2. Estimated Water Quality Impacts of the CSO and STP
Treatment Options

Receptor Area	Percent Pollution Reduction by Treatment Option		
	Combined Sewer Overflow/ Storm Sewer	Deep Ocean Outfall	Secondary Treatment
Constitution Beach	50 to 80	5 to 10	0 to 5
Dorchester Bay	60 to 90	10 to 25	5 to 15
Quincy Bay	60 to 90	10 to 20	10 to 20
Hingham Bay	--	15 to 40	15 to 40
Outer Harbor Islands	--	60 to 90	30 to 80
Brewsters Islands	--	-10 to -15	30 to 40
Nantasket Beach	--	-5 to -10	0 to 5
Massachusetts Ray	--	-35 to -45	15 to 20
Charles River	50 to 80	--	--

Note: Positive figures denote improved water quality. Negative figures
denote degradation in water quality.

Source: See Appendix A for details of the calculations.

Table 4-3. Estimates of Pollution Reduction at Receptor
Sites in Study Area (Point Estimates)

| | Percent Pollution Reduction by Treatment Option | | |
	CSO/Storm Sewer	Beep Ocean Outfall	Secondary Treatment
Constitution	70	10	5
Dorchester/Neponset Bay			
Castle Island	80	10	10
Pleasure Bay	80	10	10
Carson	80	10	10
Malibu	80	10	10
Tenean	80	10	10
Wollaston	80	10	10
Quincy	80	10	10
Weymouth	--	30	30
Hingham	--	30	30
Hull	--	30	30
Outer Harbor Islands	--	80	70
Brewsters Island	--	-15	40
Nantasket Beach	--	-10	--
Massachusetts Bay	--	-40	20
Charles River	70	--	--

Note: Positive figures denote improved water quality. Negative figures denote
degradation in water quality. Based on Table 4-2.

References

Environmental Protection Agency, June 30, 1983, <u>Analysis of the
    Section 301 (h) Secondary Treatment Waiver Application for Boston
    Metropolitan District Commission</u>, Office of Marine Discharge Evaluation,
    Washington, DC.

Metcalf & Eddy, Inc., September 13, 1979, <u>Application for Modification
    of Secondary Treatment Requirements for Its Deer Island and Nut Island
    Effluent Discharges into Marine Waters</u>, for the Metropolitan District
    Commission, Boston, MA.

Section 5

Approaches to Measuring Benefits from Water Quality Improvement

Estimates of changes due to changing ambient pollutant levels are the basis for benefit measurements. These changes include effects on human health, human activities, such as recreation, and the availability of goods and services. The economic value individuals place on the reduction of the adverse effects due to pollutants is the measure of benefits. As will be seen throughout this report, for some effects, such as ecological changes, current efforts can only, at best, delineate the physical changes; for others, either a partial or full economic evaluation is possible, This section describes the economic theory appropriate to measuring such benefits and the classification scheme used in this study.

5.1 <u>Theoretical Concepts</u>

The benefits of improved water quality resulting from implementation of pollution control options can be classified in many ways. One way is to divide them into benefits to <u>users</u> of the water resource and benefits to <u>non-users,</u> or intrinsic benefits, as presented in Table 5-1. Potential benefits from water pollution abatement accrue from current users or from intrinsic values. Current user benefits stem from either <u>indirect use</u> (near-stream activities that are enhanced by the water body such as picnicking, jogging, hiking or viewing), <u>direct use</u> of water resources for

Table 5-1.A Spectrum of Water Quality Benefits

Potential Water Quality Benefits	Current User Benefits	Direct Use	In Stream ┬─ Recreational-- fishing, swimming, boating, rafting, etc. └─ Commercial--fishing, navigation Withdrawal ┬─ Municipal--drinking water, waste disposal ├─ Agricultural--Irrigation └─ Industrial/Commercial--cooling, process treatment, waste disposal, steam generation
		Indirect Use	Near Stream ┬─ Recreational-- hiking, picnicking, birdwatching, photography, etc. ├─ Relaxation--viewing └─ Aesthetic--enhancement of adjoining site amenities
	Intrinsic Benefits	Potential Use	Option ┬─ Near-term potential use └─ Long-term potential use
		No Use	Existence ┬─ Stewardship--maintaining a good environment for everyone to enjoy (including future family use--bequest) └─ Vicarious consumption--enjoyment from the knowledge that others are using the resource.

Source: Adapted from RTI, 1983.

instream purposes (recreational and commercial), or <u>withdrawal purposes</u>
(municipal, agricultural, industrial/commercial). Intrinsic benefits are
based on non-user valuation of the existence of the resource, and on the
potential future use of the resource. Since the distinction between these
types of benefits is not always clear-cut and since many of the analytical
techniques used to measure benefits cover more than one of these types of
uses, we have chosen to reclassify the water uses according to the economic
entity to which the benefits accrue (see Table 5-2). Here, benefits flow to
households as recreators in, on or near the water and as consumers, who
benefit directly or indirectly (secondary benefits) from the increased
economic activity in the primary sectors, and to producers who use the water
resources. The benefits that will accrue from pollution abatement in Boston
Harbor are noted with an asterisk in Table 5-2.

Most of the methodologies used to measure the benefits to society from
environmental improvements are based on the theory of welfare economics and
the concept of willingness to pay (WTP). This economic theory is founded on
the principle that the "demand" for water quality is the sum or aggregate of
how much individuals of a society would be willing to pay to receive
additional increments of improved water quality. The concept of willingness
to pay has been translated into other alternative theoretical measures of
willingness to pay, including consumer surplus, compensating variation, and
equivalent variation. In simple terms, consumer surplus is the difference
between what individuals are willing to pay and what they actually pay for a
good. Figure 5-1 illustrates this individual demand function which

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a/ The following discussion is based on material discussed and presented
in RTI, 1983.

Table 5-2. Economic Benefit Categories

(Alternative Typology)

I. Benefits to Households

    A. Recreation Benefits:

        1. Swimming* ———————————————————————
        2. Fishing* ————————————————————————— Direct Use
        3. Boating* —————————————————————————
        4. Aesthetic* ———————————————————————
        5. Near-stream recreation* ————————— Indirect Use
        6. Option value* ————————————————————
        7. Existence* ——————————————————————— Potential or non-use

    B. Consumption Benefits:

        1. Commercial Fisheries*
        2. Health
            a. Swimming*
            b. Food Consumption*
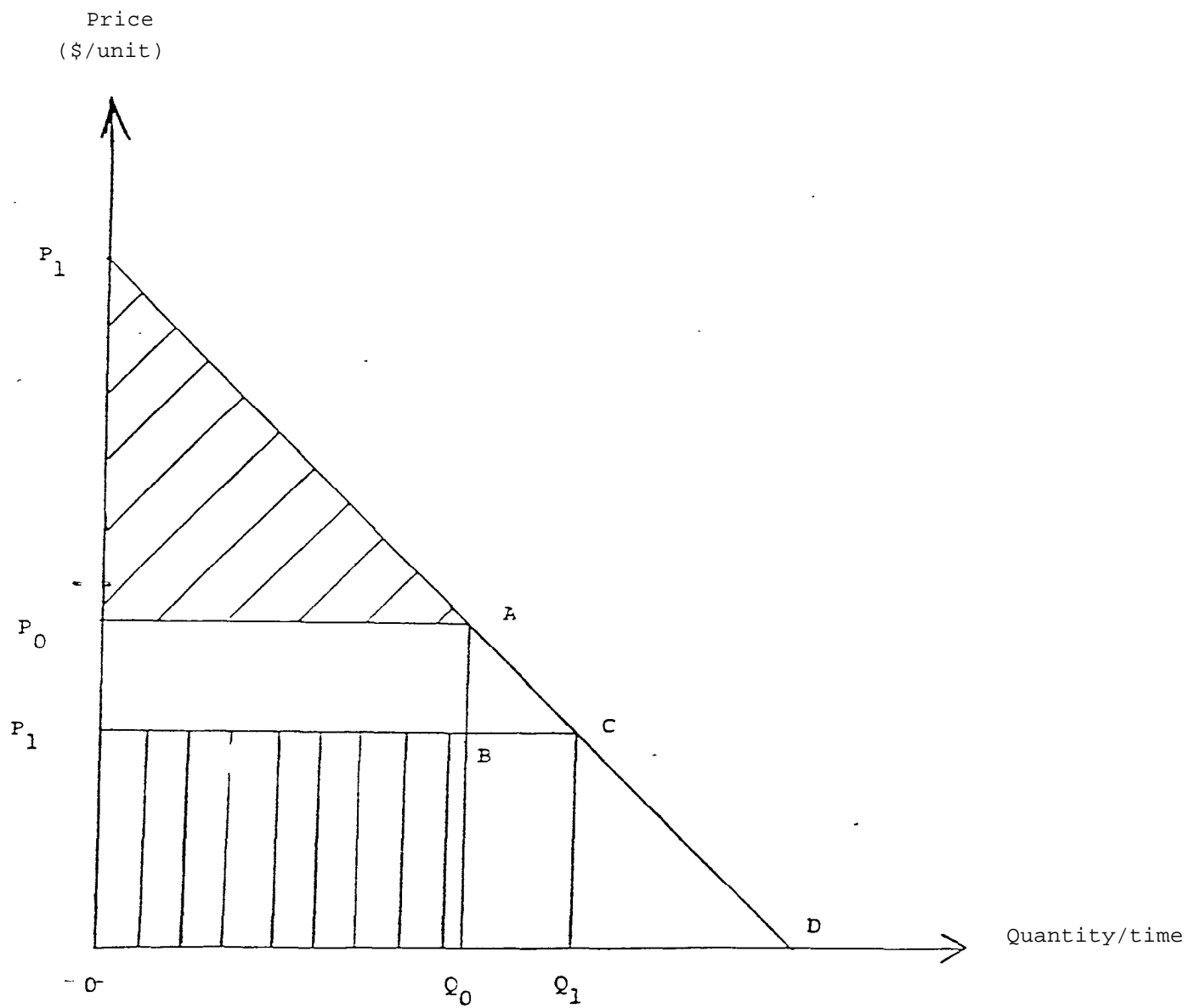

    C. Ecological*

II. Benefits to Producers:

    A. Commercial Fishing*

    B. Municipal drinking and wastewater

    C. Agricultural

    D. Industrial

    E. Navigational

III. Secondary Effects*

---

  * Benefits from pollution abatement in Boston Harbor.

Figure 5-1.   The Demand Function and
the Consumer Surplus Welfare Measure.

Price
($/unit)

Source: RTI, 1983

describes, for any commodity X, the maximum amount an individual would be willing to pay for each quantity of X.[a] The downward slope of the curve illustrates that individuals are willing to buy more of commodity X at lower prices than at higher prices. The simple two-dimensional diagram in Figure 5-1 assumes all other factors that might influence demand--income, the prices of related goods, etc.--do not change. At price P_0 the individual will purchase Q_0 of X and make a total expenditure of $P_0 A Q_0 0$. Because the demand curve measures the individual's maximum willingness to pay for each level of consumption, the total willingness to pay for Q_0 can be derived: total expenditures plus the triangle $P_j P_o A$. The difference between what individuals actually pay with a constant price per unit and the amount they are willing to pay is defined as the consumer surplus.

As a dollar measure of individual welfare, however, consumer surplus is not ideal. The most direct way of understanding its limitations is to consider the measurements underlying an ordinary Marshallian demand function. An individual's demand function describes the maximum an individual with a given nominal income would be willing to pay for each level Of consumption of a particular good. Specifically, if the price paid changes, it will affect not only what the individual can purchase of this good, but also the purchases of all other commodities through its effect on the remaining disposable income. Thus, movement along a conventional demand function affects the level of satisfaction an individual will be able to achieve with a given income. For example, suppose the price of hypothetical good X declines to P_1. The individual can purchase the same quantity of X at its new price as indicated in Figure 5-1 by the area $O P_1 B Q_0$ and have

income remaining, as given by P_1P_0AB, to purchase more X or more of other goods and services. The movement to a Consumption level of OQ_1 describes the increased selection of X under the new price. This change leads to a higher utility level because more goods and services can be consumed with the same income, For consumer surplus to provide an "ideal' dollar measure of individual well-being, however, the appropriate area under an Hicksian income-compensated demand curve rather than an ordinary Marshallian demand curve, should be used. Nevertheless, ordinary Marshallian demand curves are much easier to estimate, and Willig (1976) has shown that they provide a reasonably close approximation to the "ideal" measure.

The four "ideal" Hicksian welfare measures are summarized below (Hicks, 1943):

- Compensating variation (CV)--the amount of compensation that must be taken from an individual to leave him/her at the same level of satisfaction as before the change.

- Equivalent variation (EV)--the amount of compensation that must be given to an individual, in the absence of the change, to enable him/her to realize the same level of satisfaction he/she would have with the price change.

- Compensating surplus (CS)--the amount of compensation that must be taken from an individual, leaving him/her just as well off as before the change if he/she were constrained to buy at the new price, the quantity of the commodity he/she would buy in the absence of compensation.

- Equivalent surplus (ES)--the amount of compensation that must be given to an individual, in the absence of the change, to make him/her as well off as he/she would be with the change if he/she were constrained to buy at the old price the quantity of the commodity he/she would buy in the absence of compensation.

If commodity X in Figure 5-1 represents environmental quality, then in order to measure environmental improvement benefits it is necessary to

measure the marginal benefit curve for environmental quality, estimate the levels of environmental quality before and after environmental changes, and then calculate the area under the marginal benefit curve. This is difficult to do because there exists no explicit market for environmental quality. Therefore, a variety of alternative techniques to measuring willingness to pay for improvements in environmental quality have been developed. These techniques fit three major categories: (1) the specific damages approach; (2) the implicit market approach; and (3) the hypothetical contingent valuation approach. The specific damages approach involves monetizing a physical measure of damage per unit receptor per pollutant and combines this with the amount of receptor population. This measure is considered a crude, lower-bound proxy for willingness to pay. The implicit market approach stems from the observation that perceptions and values of environmental quality are reflected in individuals' behavior in markets related to environmental quality, such as property values or travel costs to recreational sites. The contingent valuation approach relies on surveys or bidding experiments which elicit direct measures which are contingent on the hypothetical framework from which individual valuations are obtained.

The most fundamental approach to benefit valuation is the implicit market approach, or supply/demand analysis because it enables the calculation of consumer and producer surplus at an equilibrium. The demand for water resources of a particular quality arises from a desired use activity--uses for recreational activities, industrial water uses, withdrawals for supplies, etc. Each of these uses requires a certain quality of water and the demand depends on potential uses at a given geographic location. To evaluate the

effects of changes in water quality, demand for a use activity must be calculated. It is not always possible, however, to conduct demand curve estimation for benefit calculations. In reality, only a partial form of demand analysis can be done. Moreover, the success (or reliability of the estimate) of the analysis varies by benefit category,

For an in-depth discussion of these issues and methodologies that are used to estimate economic benefits from pollution abatement see Freeman, The Benefits of Environmental Improvement (1979), and Air and Water Pollution Control: A Benefit-Cost Assessment (1982); Feenberg and Mills, Measuring the Benefits of Water Pollution Abatement (1980); and Research Triangle Institute, A Comparison of Alternative Approaches for Estimating Recreation and Belated Benefits of Water Quality Improvements, (1983).

5.2 Study Methodology

Our strategy in this study is to employ methods developed by previous researchers and to compute benefits for each category using a variety of estimation techniques whenever possible.

The various categories of effects (or beneficial use classes) are summarized in Table 5-3. The table also indicates the approach which has been used to estimate the effect/benefit, and an evaluation of the reliability and availability of the methodology and data.

Table 5-3

Benefit Categories and Methodologies for Boston Harbor Study Area

Benefit/Effect	Benefit Estimation Approach	Reliability of Methodology	Reliability/ Availability of Data
Recreation			
Swimming	o Travel cost (logit model)	excellent	excellent
	o Regional participation	good	fair to good
	o Beach closings cost savings	fair	fair to good
Boating	o Regional participation	fair	fair
Fishing	o Regional participation	fair	fair
Health			
Swimming	o Dose-response function (incidence of disease)	excellent	good
Food consumption	o Dose-response function (incidence of disease)	good	fair to good
Commercial fisheries	o Demand and supply functions	good	poor
Intrinsic Benefits	o Contingent valuation survey		
	o Direct % of recreation benefits	fair good	fair good
Ecological	o No approach available *to* apply a dollar value for benefits	--	--
Secondary Effects	o Input-output multipliers	fair	fair

References

Feenberg, Daniel and Edwin Mills, 1980. <u>Measuring the Benefits of Water Pollution Abatement</u>, Academic Press, New York, NY.

Freeman, A.M. 1979. <u>The Benefits of Environmental Improvement</u>, Johns Hopkins University Press, Baltimore, MD.

Freeman, A.M., 1982. <u>Air and Water Pollution Control: A Benefit-Cost Assessment,</u> John Wiley and Sons, Inc., New York, NY.

Hicks, John R., 1943. The Four Consumers' Surplus, <u>Review of Economic Studies</u>, 11:31-41.

Research Triangle Institute, 1983. <u>A Comparison of Alternative Approaches for Estimating Recreation and Related Benefits of Water Quality Improvement,</u> Research Triangle Park, North Carolina, EPA.

Willig, Robert D., 1976. Consumer Surplus Without Apology, <u>American Economic Review,</u> 66:589-597.

Section 6

Recreation Benefits

The recreation benefits of improving water quality in Boston Harbor are many. Boston Harbor is surrounded by a major metropolitan area of 2.8 million people and provides a setting for many diverse water uses including boating, sailing, canoeing, fishing , swimming and beach activities. In addition, in recent years the harbor has become an aesthetic focal point for water-enhanced recreation activities such as picnicking, bicycling, camping, hiking and sight-seeing. Figure 6-1 shows the various locations (called receptor sites) of these water uses.

Although the CSOs and the STPs affect some of the same harbor areas of the study, in general the receptor sites are primarily affected by one or the other source. The CSOs affect recreation areas closest to the shore and, thus, have the greatest impact on swimming and shore-related fishing and boating. Of all the CSO planning areas, Dorchester Bay is influenced the most because of the great concentration of CSOs and beaches in the bay. The Quincy storm sewers affect water quality at local town beaches and Wollaston Beach. The Charles River CSOs have a major impact on boating. This area is discussed separately in Section 11 because of differences in data bases and the nature of the water resources.

The areas primarily affected by the STP discharges are the waters and islands surrounding the STP outfalls. Beaches in the towns of Quincy,

Figure 6-1.   Receptor Areas for the Boston Harbor Study
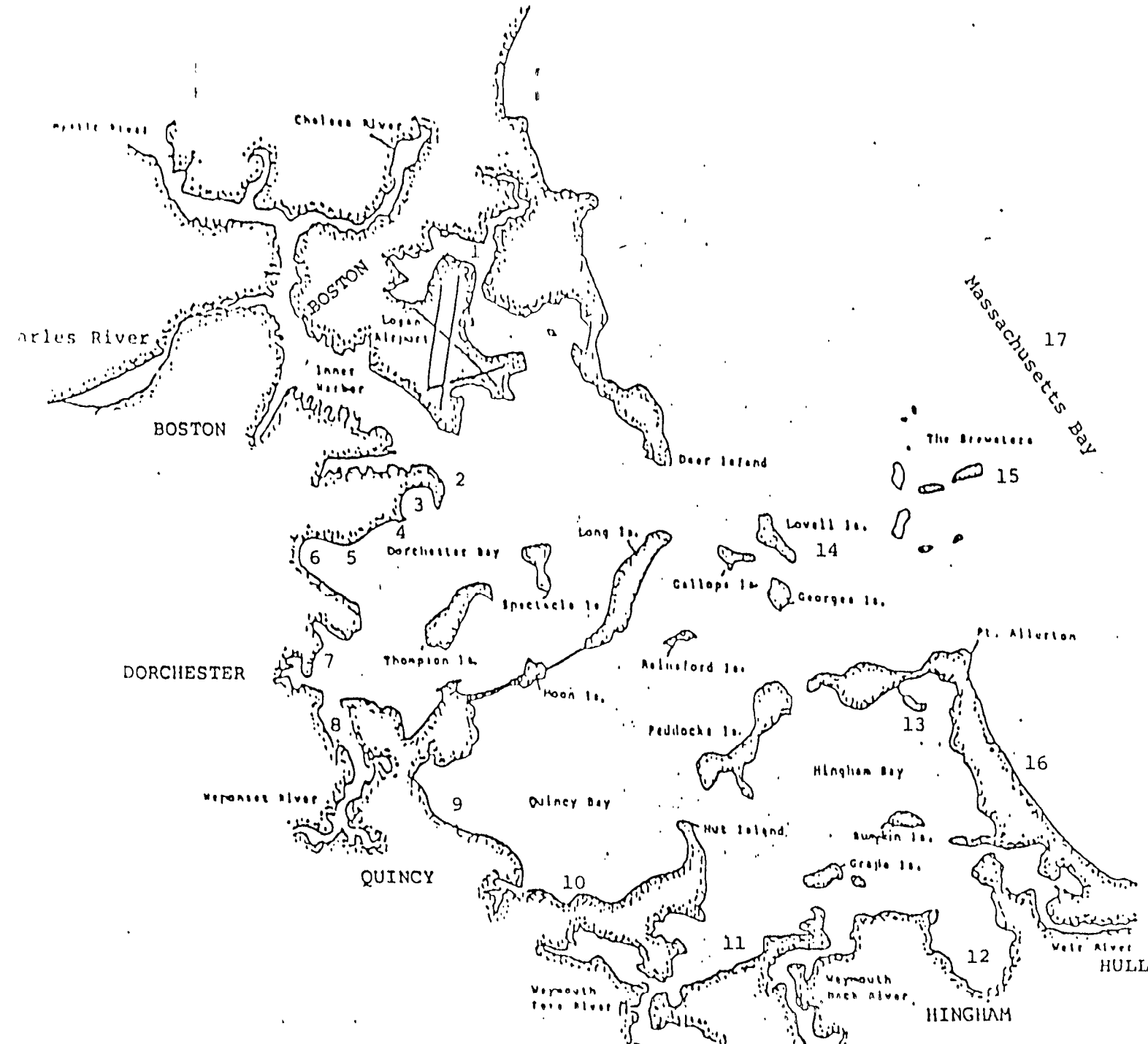
1. Constitution Beach
2. Castle Island
3. Pleasure Bay
4. City Point
5. L&M Streets Beach
6. Carson Beach
7. Malibu Beach
8. Tenean Beach
9. Wollaston Beach
10. Quincy Town Beaches
11. Weymouth Bay
12. Hingham Harbor
13. Hull Bay
14. Outer Harbor Islands
15. Brewsters Islands
16. Nantasket Beach
17. Massachusetts Beach

Weymouth, Hingham and Hull and the Boston Harbor Islands are the swimming areas primarily affected by the STPs.

The Boston Harbor Islands--Slate, Bumpkin, Grape, Gorges, Lovells, Gallups, Deer, Long, Rainsford, Moon, Thompson, Spectacle, Sheep, Peddocks, and the Brewsters--are a unique natural resource in a metropolitan area Possessing only one-half of the recommended minimum acreage of open space per thousand population. The Islands offer a wide range of activities such as boating, swimming, picnicking, fishing, hiking, camping, scuba diving, and historic sight-seeing. Many of the islands have limited recreational facilities which restrict current and potential visits. Poor water quality, however, is also a major factor restricting recreational activities. Effluent from Deer and Nut Island sewage treatment plants seriously degrades water quality around the Islands, particularly discouraging swimming and fishing. Assuming that the planned recreational facilities were constructed, then upgrading the plants and/or discharging the effluent into the ocean would lead to a significant improvement in water quality, which would lead to a corresponding increase in both frequency of participation and total number of visitors. [a]

Fishing and boating are also affected by the STPs since a large percentage of these activities take place in the outer harbor study area rather than on or near the shore. Participation in all boating--sailing, motor boating, canoeing and windsurfing--and fishing activities in Boston Harbor is expected to increase with decreases in water pollution levels. [b]

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[a] The exception to this assumption is the Brewsters Islands and Nantasket Beach, which are expected to be negatively influenced by the ocean outfall option.

[b] The degradation of water quality in Massachusetts Bay under the ocean outfall option is expected to primarily affect commercial fishing.

6.1 Data Needs and Data Bases

The data needed to estimate recreational activity in these various areas and to relate the uses to changes in water quality come from a variety of sources. This section discusses the data bases used to estimate recreation benefits. It is followed by a discussion of the various methodologies which have been applied to the Boston Harbor case to arrive at a range of benefit estimates for each separate benefit category.

6.1.1 Swimming Attendance

Seven of the beaches managed by the Metropolitan District Commission (MDC) are affected by CSOs and/or STPs in the study area: Constitution Castle Island, Pleasure Bay (including City Point), Carson,[a] Malibu, Tenean, and Wollaston. Nearby cities and towns also have small neighborhood beaches which are affected by pollution control sources. The cities of Quincy, Weymouth, Hingham and Hull recognize ten beaches besides Wollaston for water quality collection purposes. In addition, swimming occurs on an informal basis on many of the eleven Boston Harbor Islands. Rough estimates put recent seasonal attendance of all these affected beaches at 4.0 million people (see Table 6-1). Unfortunately, neither the MDC, the towns, nor the Massachusetts Department of Environmental Management (DEM) keep attendance records or make official counts during the season. In addition, people swim at the beaches during warm weather in the spring and fall, even though they are not officially open. Information from a 1975 recreation survey (Binkley and Hanemann) and from the MDC indicate that some of the Boston area beaches

[a] L and M Street Beach, part of Carson Beach, is managed by the City of Boston.

Table 6-1. Seasonal Swimming Supply

Current Seasonal Beach Attendance	Seasonal [a] Capacity	Seasonal [b] Excess Supply
Constitution		
325,000	582,780	257,780
Dorchester/Neponset	5,044,878	4,454,878
590,000		
Castle Island		
15,000	291,390	276,390
Pleasure Bay		
175,000	1,548,155	1,373,155
Carson		
100,000	1,899,774	1,799,774
Malibu		
150,000	632,449	482,449
Tenean		
150,000	673,110	523,110
Wollaston		
2,750,000	4,595,976	1,845,976
Quincy		
158,900	320,568	161,668
Weymouth		
105,820	763,680	657,860
Hingham		
22,200	355,200	333,000
Hull		
66,000	532,800	466,800
Nantasket Beach	[c]	[c]
3,035,000		

[a] Based on 40 ft^2 per person: turnover of 3 times per day; 29.6 peak user days per season. Except Wollaston Beach with four times per day turnover and 39.4 peak user days per season. (Derived from US Department of Interior, 1970.)

[b] Excess supply = (Capacity) minus (Current attendance).

[c] Not applicable since expect degraded or unchanged water quality.

Source: See Appendix B, Table B-1.

Note: Brewsters Islands are omitted because most of the recreational activity is fishing and boating, and Massachusetts Bay is omitted because the primary activity is commercial fishing.

draw people from many parts of the Boston Metropolitan area. Other beaches appear to be used almost exclusively by people from a nearby section of the city, such as arson Beach by South Boston residents and Constitution Beach by East Boston residents.

Attendance data used for calculating swimming benefits were estimated by MDC personnel and by recreation and park department officials in Quincy, Weymouth, Hingham, and Hull. We also compared attendance figures reported by the MDC in the 1975 Binkley and Hanemann study along with attendance figures generated from a survey used in their study. This range of values can be found in Table B-1, Appendix B. Data on beach acreage and/or linear feet of beach/shoreline was also supplied by the MDC and municipalities and was used to develop a range of beach capacities for each affected area based on national recreation standards. Estimates for beach capacity and beach attendance numbers are presented in Table 6-1. These attendance and capacity figures are used in several approaches to calculating swimming-related benefits in this report. The accuracy of these methods is linked to the accuracy of the recreation data.

Other factors could also act to limit the increased participation predicted as a result of water quality improvement. They include crowding and congestion, available parking facilities, presence of jellyfish and, particularly for Boston Harbor, cold temperatures of the air and water. Although these effects can be significant, the first three factors were not considered here because of insufficient data. The effects of air and water temperatures were incorporated in a lower bound estimate of increased participation.

As a qualitative assessment, we have assumed that crowding would not have as severe an impact on the study area beaches as in other recreation areas because these beaches are extremely urban and, as one municipal source noted, visitors are used to constant crowding.

Parking facilities close to the beaches could limit visits on a given day as these beaches are used by people throughout the area. Currently, the MDC estimates that on a normal sunny day parking is at 80 percent of capacity although on the hottest days demand for parking greatly exceeds capacity and substantial traffic congestion occurs. Beachgoer preference is to drive to the beach rather than use public transportation which is available and convenient to the cities' beaches. Thus, alternatives to parking do exist if the increased participation should exceed the available parking supply.

With regard to jellyfish, there are practically no data available on this form of life except for some research done in Chesapeake Bay by the University of Maryland's Chesapeake Bay Laboratory. Most of the work has been done in open ocean. Observations in Boston Harbor indicate the presence of a substantial jellyfish population, The fish are present throughout the summer months and, in 1984, have been observed as early as April. The prevalent theory is that polluted water promotes an algae growth within the jellyfish food chain and the population increases in accordance with the food supply. However, scientists caution that there is no evidence to support this theory. Jellyfish are considered to have little food value and consequently have no predators to act as a population control mechanism. Population levels are thought to be decreased by storms, currents and changes in the salinity of the marine environment. The introduction of fresh water

into the harbor through CSO's could result in reduced salinity which in turn could promote or deter jellyfish population growth. However, a lack of data makes the issue speculative. An agreed to fact is that the presence of jellyfish in the waters generates an adverse public reaction and acts as a deterrent to water contact activity and, possibly, increased visits to the beaches on days when jellyfish are present. [a]

In attempting to account for the effects of air and water temperature on swimming attendance, for an upper bound estimate the base seasonal attendance figures are limited to the three summer months. For a lower bound estimate the predicted increased attendance is modified according to the distribution of air temperatures during these summer months. [b] On those days with cooler temperatures not all the predicted increased participation due to improved water quality is assumed to take place. Thus, a factor is applied reducing the upper bound estimate in relation to the distribution of air temperature during the summer months (see Appendix B.3).

6.1.2 Recreation Studies

Information on general recreational activities such as percentage of population participating in swimming and percentage of unmet demand for boating and fishing was drawn from a number of existing city, state and federal reports. These include, the New York-New England Recreational Demand Study (Abt, 1979), the 1980 National Survey of Fishing, Hunting and Wildlife

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[a] Information in this section was provided by EPA, Region I, Boston, MA.

[b] Air temperature is assumed to affect beach attendance. Air and water temperature are assumed to affect the amount of swimming done by those who go to the beach (and are taken into account in estimating swimming health benefits in Chapter 7).

Associated Recreation (US DOI), The 1982-1983 Nationwide Recreation Survey (US DOI), Eastern Massachusetts Metropolitan Area Study (EMMA), (Metcalf & Eddy, 1975), Boston Harbor Islands Comprehensive Plan (Metropolitan Planning Council, 1977), and the Massachusetts SCORP (Massachusetts DEM, 1976). Not all of the information in these studies is specific to Boston Harbor nor does each study supply exactly what is needed for estimating pollution abatement benefits. For example, there is some information about swimming and beach-related activities, but there is very little information available describing fishing and boating activities. In addition, much of the data in these studies are only estimates, rather than statistically-derived results from rigorous sampling, which compromises their use in benefit estimation techniques. We have evaluated a number of these recreation studies for their accuracy, sampling methods and applicabilty to the Boston Harbor case study, and have used only those statistics and numbers which we believe to be representative and unbiased. A brief discussion of each recreational source can be found in Appendix B.7.

6.1.3 Water Quality Data for Logit Model

Water quality data is needed for the application of the travel cost logit model (see Section 6.2.2 below).[a/] There is information about ambient water quality concentrations throughout most of the harbor but it is of limited usefulness due to the shortcomings in sampling procedures (frequency, consistency, regularity, comprehensiveness) and in the comparability of the measurements used to describe water quality, Recently, the MDC has started a water quality sampling program to better identify ambient concentrations of a variety of Pollutants such as BOD_5, heavy metals, oil and grease.

[a/] At the time the logit model analysis was run the Boston Harbor Data Management System was not available so that this data had to be collected independently.

Currently, the only readily available water quality data for the MDC and town beaches are measures of fecal and total coliform concentrations. Binkley and Hanemann (1975) collected water quality samples for a number of water quality parameters to be used in their recreational travel cost model, but we have chosen not to use any of their data because water quality samples were only taken once during the summer and thus cannot be considered statistically representative of water quality for the entire swimming season. For this Boston Harbor case study, we collected 1974-1982 fecal and total coliform concentrations and information on beach closings/postings, from the seven MDC beaches and several town beaches in Quincy, Weymouth, Hingham and Hull. In general, the MDC and towns sampled once a week, resampling when high counts were recorded. In cases where only total coliform concentrations were reported, we substituted fecal coliform values based on a statistically significant regression function relating fecal coliform concentrations to total coliform concentrations (see Appendix C). This water quality data, together with data from several other towns in the Boston Metropolitan area, was used in the travel cost logit model.

6.1.4 User (Unit) Day Values

The application of user day values to estimate recreation benefits is the most common and widely used of all the estimation techniques because of its simple methodology and minimal data requirements. Essentially, a single dollar value per recreation day (not per visit) is developed to represent the market value of the recreation services. Originally, this figure per recreation day was based on recreational costs including entrance charges and equipment expenditures. The federal government has adopted a schedule of values to distinguish between "general" and "specialized" recreation

activities.[a/] A single unit value is assigned per recreation day regardless
of whether the user engages in one activity or several. This value should
reflect the quality of the activity and the degree to which opportunities to
engage in a number of activities are available (Dwyer et al., 1977). We have
reviewed a number of user day values for their applicability to Boston Harbor
and present the values and their sources in Appendix B, Table B-3.

There are many shortcomings and problems with using user day values to
estimate recreation benefits. These limitations are discussed in detail in
Dwyer, et al., 1977. The most basic problem is that most user day
values--whether based on government or private schedules--may not be developed
from empirical data on the actual willingness of participants to pay for
recreation. This lack of theoretical or empirical justification for many user
day values often leads to arbitrary and biased estimates of the value of a
recreation day.

User day values have been developed both nationally and locally. Many of
these values tend to be site-specific , reflecting regional socio-economic
biases and, more often than not, cannot capture the effects of incremental
changes in environmental quality. In addition, user days cannot capture the
increased value or utility of the individual recreator. As a result, user
day values may produce biased estimates of consumer surplus from improved
water quality.

6.1.5 Water Quality Impact

All of the above categories of data are needed to evaluate the response of
recreators to water quality changes. The remaining piece of data that is

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[a/]See Federal Register, Vol. 48, No. 48, March 10, 1983.

needed is what the estimated percentage change in water quality will be, given the implementation of a treatment option. Section 4 explained how the percentage reductions in pollution were estimated for the various receptor sites. Table 4-2 and 4-3 presented best-guess ranges and point estimates of the water quality changes. We use these numbers in the benefit calculations.

6.2 <u>Benefits</u>

    Reducing pollution in the harbor by upgrading STPs and improving CSOs will lead to recreation benefits throughout the Boston Harbor area. Two major components of consumer surplus should be estimated in order to fully represent <u>all</u> benefits from improved water quality. These components are:

- o   increase in participation (both frequency and total numbers)
    - resulting from decreased time and travel costs
    - resulting from a higher quality recreational experience
    - resulting from increase in water areas available for recreation; and
- o   increase in the price participants are willing to pay (WTP) for the improved quality of the recreational experience.

A third component can be measured by calculating the value of lost participation due to severe water contamination , such as that resulting from beach closings.

    We have used a number of techniques to calculate a range of economic recreation benefits associated with improving water quality in Boston Harbor by upgrading the sewage treatment plants and improving the CSOs. These include:

<u>Benefit</u>	Measure of <u>Consumer Surplus</u>	<u>Benefit Estimation Approach</u>
Swimming	o Increase in participation	o Regional participation o Travel cost (logit model)
	o Increase in WTP per trip	o Travel cost (logit model)
	o Lost participation	o Beach closings

	Measure of	
Benefit	Consumer Surplus	Benefit Estimation Approach
Boating/ Fishing	o Increase in participation	o Regional participation
All Recreation Boston Harbor Islands	o Increase in participation	o Regional participation

Each of these estimation techniques and benefits categories are discussed separately, below. Included in this discussion is a presentation and analysis of the range of benefit values corresponding to the pollution abatement program, limits of the analysis, and pertinent references. A detailed description of the benefit computations and the empirical data is presented in Appendix B.

6.2.1 Swimming--increase in Participation

One of the significant consumer surplus benefits associated with water pollution abatement in the Boston Harbor study area is the increased use of the beaches by current users and new use by previous non-participants. This is one of the more difficult benefits to measure because of the need for reliable and accurate calculations of user and non-user response. For Boston Harbor, we have assumed that an improvement in water quality-specifically fecal coliform--is equivalent to an increase in total supply of the water resource. Theoretically it is therefore possible to relate this increase in a water resource to a corresponding increase in participation. Increased participation, measured in total visits, should capture both increase in frequency of visits by those already participating, as well as increased new use by previous non-users. Once this population number is calculated, it is possible to value this increased participation by applying user-day values.

Estimating benefits accruing from increase in participation involves the following:

a)   determine which areas are affected by each pollution control plan;

b)   calculate excess seasonal beach supply;

c)   estimate the range of increase in participation using information from regional participation studies;

d)   relate the increase in participation to the pollution control plan; then

e)   value increased participation by applying a range of user day values.

The first step in estimating the benefits from increased participation involves determining which beaches are affected by the different treatment options.   These were determined in Section 4 and presented in Table 4-3.   The next step is to calculate the excess supply of each beach, such that increased demand will not exceed the existing supply,   This will prevent overstating swimming benefits.   Excess seasonal supply of these beaches was estimated using beach attendance data from the MDC and towns, and the capacity of each beach was calculated using a variety of recreational standards and information from town governments and the MDC on acreage and linear feet of shoreline. This data was summarized in Table 6-1.   Other factors could serve to limit increased participation, as discussed in Section 6.1.1.   However, these effects were not considered here because of insufficient data.

6.2.1.1 Regional Participation Model

The most important step in this methodology involves estimating a range of increased participation.   The first approach presented here to estimating increased participation is based on regional and local

recreation participation studies. Results of these studies suggest that the number of unmet user days (often called latent demand) in the Boston SMSA is 4.3 to 5.2 million user days. Using this information, we can calculate unmet demand at the beaches that will be supplied by the different pollution control options. These calculations are summarized in Appendix B.1. It is possible to relate this total increase in beach participation to the pollution control plans by assuming that the percentage reduction in pollution will supply a corresponding percentage of the excess supply in terms of additional user days. A number of other assumptions were made in order to calculate increase in participation:

(a) water quality is the major constraint affecting unmet demand;

(b) current facilities are adequate to fulfill the needs of additional visitors;

(c) time available for recreation is not a constraining factor;

(d) fecal coliform is the best <u>available</u> measure of overall water quality affecting participation;

(e) there is little effect of substitution of sites on participation at individual beaches; and

(f) people use the beaches for swimming purposes.

These assumptions and calculations produce the upper bound estimates of increased user days presented in Table 6-2. For the lower bound estimates a factor based on the distribution of air temperatures during the summer months is applied. It is assumed that on days when the air temperature is below 79° Farenheit, not all the predicted increase in beach visits may actually occur even with the improved water quality because of the relatively lower air temperature (see Appendix B.3 for details of the calculations).

Table 6-2. Increased Swimming Participation--Regional
Participation Model $\underline{a}/$

Beach	CSO	Ocean Outfall	Secondary Treatment	CSO and Ocean Outfall	CSO and Secondary Treatment
			LOWER BOUND ESTIMATES (User Days)		
Constitution	76,099	10,871	5,436	86,970	81,535
Dorchester	157,884	19,736	19,736	177,620	177,620
Wollaston	735,900	91,988	91,988	827,888	827,888
Quincy	42,522	5,315	5,315	47,837	47,837
Weymouth	0	10,619	10,619	10,619	10,619
Hingham	0	2,228	2,228	2,228	2,228
Hull	0	6,623	6,623	6,623	6,623
TOTAL	1,012,485	147,380	141,945	1,159,785	1,154,400
			UPPER BOUND ESTIMATES (User Days)		
Constitution	113,750	16,250	8,125	130,000	121,875
Dorchester	236,000	29,500	29,500	265,500	265,500
Wollaston	1,100,000	137,500	137,500	1,237,500	1,237,500
Quincy	63,560	7,945	7,945	71,505	71,505
Weymouth	0	15,873	15,873	15,873	15,873
Hingham	0	3,330	3,330	3,330	3,330
Hull	0	9,900	9,900	9,900	9,900
TOTAL	1,513,310	220,298	212,173	1,733,608	1,725,483

$\underline{a}/$ See Appendix B for details of the calculations.

An alternative approach to estimating increase in participation is to use results from the logit model (described below in Section 6.2.2) which predicts increased visits based on a percent reduction of water pollutants to calculate unmet demand.

It is important to compare the estimates of increased participation due to increases in water quality with the availability of excess supply, in order not to overestimate swimming benefits. We have assumed in the case of the Dorchester/Neponset Bay beaches that if increased participation exceeds capacity at any one beach, then other nearby beaches will serve as substitute sites. This enables us to treat the Dorchester Bay beaches as a unit, rather than individually, and simplifies the analysis.

6.2.1.2 <u>Benefit Estimates</u>

The final step in this methodology is to value the increased participation by applying a range of appropriate user day values, which represent a crude proxy for individual consumer surplus. The results of this valuation are presented in Table 6-3.

Table 6-3. Annual Benefit of Increased Swimming Participation for all Boston Harbor Beaches (1982 $000)

User Day Value	CSO	Ocean Outfall	Secondary Treatment	CSO plus Ocean Outfall	CSO plus Secondary Treatment
$1.60	1,620.0 <u>a</u>/	235.8	227.1	1,855.7	1,847.0
$5.80	7,324.8 <u>b</u>/	1,066.3	1,026.9	8,390.8	8,351.7
$11.06	16,737.2 <u>c</u>/	2,436.5	2,346.6	19,173.7	19,083.8

<u>a</u>/ Lower bound estimate of increased visits (from Table 6-2) multiplied by user day value (from Table B-3, Appendix B).

<u>b</u>/ Average of lower and upper bound estimates of increased visits multiplied by user day value.

<u>c</u>/ Upper bound estimate of increased visits multiplied by user day value.

There is a wide range of estimated benefit values for increased
Participation because of the many different user day values. Benefits are
most substantial for the Dorchester/Neponset Bay Beaches and for the
Wollaston and Quincy Beaches. Benefits are more modest for Constitution
Beach. Benefits are substantial for Dorchester/Neponset Bay and
Wollaston/Quincy beaches because these areas have poor water quality, a large
predicted percent cleanup, and a great number of visitors. Thus, cleaning up
these areas will attract a large number of new recreators and significantly
increase the frequency of participation of current users. Swimming benefits
from an increase in participation are small for the STP affected beaches
because of the fewer number of people who visit these beaches and because the
STP option is expected to abate pollution by only 30 percent.

6.2.1.3 Higher Valued Experience

Improved water quality may also lead to an increase in the price that
participants are willing to pay for the improved quality of the recreation
experience. This higher valued experience is often very difficult to
quantify. Other benefits studies have relied upon surveys of willingness to
pay for various improvements in recreational water quality (See for example,
Ditton and Goodale, 1972 and Ericson, 1975). Such surveys are often locally
biased and, thus, cannot be applied to other areas because of sociological,
environmental and economic differences.

No such studies were found to be applicable to Boston Harbor because of
the previously mentioned biases. We therefore, were unable to calculate the
portion of consumer surplus attributable to a higher valued experience using
this method.

6.2.1.4 <u>Limits of Analysis</u>

An analysis of increased participation was limited by both benefit
estimation methodology and by data bases. Latent or unmet demand was
difficult to measure. Estimates were based on results from regional and
local recreational studies, which may be inaccurate for a number of reasons.
(For more details see Appendix B.7.) The accuracy of our benefit estimates
is greatly influenced by recreation attendance data and capacity estimates.
Current attendance figures were based on professional estimates, rather than
actual field data, and thus must be considered "best guesses". In addition,
these estimates of attendance figures were based on seasonal summer
attendance, from Memorial Day to Labor Day , and did not include the number of
people who swim before or after the "summer" season. Benefits to these
recreators are not captured and, therefore, total benefits may be
understated. Beach capacity estimates also represent our best professional
judgment. For example, Wollaston has an estimated capacity of 2.75 million
people, but the MDC has estimated seasonal attendance to be over 3.5
million. In this case we concluded that the development capacity for
Wollaston represents a lower bound and assumed a greater turnover rate than
normal and a greater than expected crowding. Other factors, including
adequate parking facilities, cold water temperatures and the presence of
jellyfish which could limit attendance in a manner similar to beach capacity
were not considered because of the lack of data.

These benefit estimates are also limited by the many assumptions which
were made, including assumptions about the appropriateness of fecal coliform
as the best <u>available</u> water quality indicator, time constraints, and the
effect of water quality improvement on increased participation. It was

assumed that many relationships were strictly linear, such as the relationship between percentage increase in use and the percentage reduction in water pollution. Such an assumption seems feasible here, since the baseline water quality level is so poor; however, in general, the relationship between percentage reduction in pollution and percentage increase in participation is very sensitive to the baseline water quality level. For example, a 90 percent reduction of pollution in a water body that has relatively good water quality may result in little or no increase in participation. We also assumed that user day values were the best available proxy for consumer surplus. In reality, user day values cannot capture total consumer surplus because they cannot measure increased utility of each visit due to improved water quality The higher range of user day values ($5.80-$11.06) is, therefore, more appropriate to use than the lower one ($1.60-$5.80) in estimating recreation benefits. All of these limitations, shortcomings and the state- of-the-art nature of benefit estimation will be reflected in the final range of swimming benefits and must be taken into consideration when interpreting the values.

6.2.2 Travel Cost Model--Conditional Logit Analysis

An alternative apporach to estimating increased participation is the logit model which incorporates the probability of visiting a beach as a function of distance to the sites, socioeconomic factors and water quality variables. This approach is a specialization of the so-called travel cost approach first suggested by Harold Hotelling in 1949, then developed by Clawson and Knetsch (1966), and since applied by many others (see Binkley, 1977, for a review of the literature).

6.2.2.1 Methodology

     This methodology uses observed recreation travel patterns to infer the recreationists' response to price changes. Travel costs play the role of price in estimating a demand curve for a specific site. Other personal characteristics of the recreationist, such as income and age, are used in the same equation to control for tastes and preferences. Because a demand curve measures the marginal willingness to pay for a good, estimates of recreation benefits can be obtained from the area under a demand curve using travel cost data and information on socioeconomic characteristics. In the present case, we extend this basic methodology to include water quality characteristics in the demand function. Then we can infer the changes in price which would be equivalent to a change in water quality, and from that information can infer the benefit of the change in water quality.

     The principal theoretical shortcoming of this approach is the use of travel costs to simulate prices. The recreationist may not respond to prices (i.e., an entry fee) in the same way as he/she does to travel costs because travel may have a special utility or disutility in itself. Part of the disutility of travel might be related to travel time as well as travel costs. (See below for a further discussion of the time issue.) Another common difficulty in the application of the travel cost method is the allocation of joint costs of travel made to several recreation sites as part of a single trip. Because travel costs are used as a proxy for prices, to determine the "price" of an individual site it becomes necessary to separate the cost of travel to one site from that to other sites. Consider, for example, a trip from Boston to the Grand Canyon, then to Yellowstone National Park, and then back to Boston. To infer the recreational value of the Grand

Canyon from this trip, we would need to know what part of the travel costs

associated with the whole trip to assign to the visit to the Grand Canyon.

The appropriate cost is probably less than the total cost, but could well be

more than just the additional cost of including the Grand Canyon in the

trip. In short, there is no unambigious way to allocate joint costs of

recreation travel. Fortunately, day trips in an urban setting are not likely

to be conducted as part of a larger recreational outing, so our analysis

probably does not suffer from this limitation.

It is important to discuss the major ways that our methodology differs

from the classic implementation of the travel cost approach. First, we

consider a system of competing recreation sites. That is, demand for

recreation at one site depends on the characteristics of other possible

recreation sites that an individual might choose. To our knowledge, aside

from the direct antecedents of this work, only three other studies (Cicchetti

et. al, 1976; Burt and Brewer, 1971; Morey, 1981) have incorporated this

important feature of the problem.

Second, we attempt to explicitly account for travel time as well as

travel cost. It is easy to show that ignoring the cost of time spent in

recreation leads to biased estimates of the value of a recreation site. This

point is well-recognized in the literature (see, for example, Wilman, 1980).

The following section on the conditional multinomial logit model acknowledges

the empirical difficulties we had in obtaining usable estimates of the value

of time and discusses this point further.

Third, we model recreational demand as a discrete choice process. That

is, over the summer the individual chooses to go to some sites, perhaps none,

but probably not to all the available sites. Consequently there are

typically quite a few observations of zero visits , and these observations tell us very little about how he/she trades off water quality with travel distance.   Therefore, we would like a model of recreation demand which explicitly accounts for the kind of information contained in this large number of zero observations.   The multinominal logit model, borrowed from transportation demand analysis, is one such model.   This model was first proposed for recreation demand analysis by Binkley and Hanemann (1975) and subsequently has been developed by Hanemann (1978) and by Feenberg and Mills (1980).   Peterson et. al (1983) applied a version of this model to activity choice at the Boundary Waters Canoe area.

    The first three studies rely on the same basic data.   In 1974, a sample of 500 households representative of the Boston SMSA were interviewed concerning their recreation visits to 29 fresh and saltwater beaches in the Boston area during that summer.   A total of 467 usable questionnaires resulted from the survey.   Pertinent social and economic data on these families were collected along with information on recreation habits.   To compute travel distance and, hence, cost, each of the sample points was located on a map as were each of the recreation sites.   In the original three studies, travel distance was computed as the straight line distance between the two points.   Also, water quality variables used in the demand equations were derived from one single sample at each beach during July of 1974. (Binkley and Hanemann, 1975, describe the data more fully.)

    While sharing a common estimation strategy with these other three studies, the present work employs a somewhat different data base.   Recreation patterns and socioeconomic data from the Boston survey were used, but improved information on travel costs and water quality was incorporated. In an urban

area, straight line distance is a particularly poor measure Of actual travel

distance.   Fortunately, in the mid-1970's the Central Transportation Planning

Staff (CTPS), a regional transportation planning agency for the Boston area,

developed a detailed origin-destination travel distance and time matrix for

the region.   Our sample points and beaches were located in the CTPS

transportation zones, and the minimum travel distance and time from each

sample point to each beach was computed.   Consequently, the measure of

distance used in this research reflects much more accurately the actual

distance between each individual and the various beaches.   In addition, the

transportation time information derived from the CTPS study offered the

possibility of estimating the value of time in travel for recreation.

   Due to large sampling errors, the "old" (Binkley and Hanemann, 1975)

measure of water quality--a one time grab sample--might not reflect the true

water quality level.   We assembled measures of coliform levels from the

records of the Metropolitan District Commission and the appropriate towns.

These were averaged over the summer, and we employed the median level of fecal

coliforms as our "new" measure of water quality.   The agencies responsible for

some of the beaches did not collect information on fecal coliforms.   For these

cases, a regression equation was developed relating the old water quality data

to the new estimate of fecal coliforms.   For the sites where there was no new

information, this equation was used to estimate the new data from the old data

on fecal coliform (OLD):

$$\text{NEW} = -53.27 + 13.22 \log (\text{OLD}) \qquad N = 19$$
$$\qquad (-1.99) \qquad (3.17) \qquad\qquad R^2 = 0.371$$

6.2.2.2 The Conditional Multinomial Logit Model

The multinomial logit model of multiple site demand is ideally suited for the situation we consider here: the choice of one or more beaches from a known universe of possible sites.[a] This section describes the model informally and explains how we obtain estimates of the benefits of water quality improvements from the model. Appendix B.4 presents the model and benefit estimation procedures in more detail.

We want to model the number of visits an individual will make to one or more of the beaches as a function of beach characteristics (including water quality), travel costs/time, and socio-economic characteristics of the individual. With such a model, we can alter the level of water quality at one or more of the sites and simulate how use at all of the sites will change. From those simulated changes in use, we can infer the value of the change in water quality.

The conditional logit model is divided into two parts. The first part describes the probability that an individual will choose to visit each of the beaches given that she/he takes a trip to any of the sites. Equivalently, this part of the model can be thought of as predicting the proportion of all beach visits which will be made to each of the individual beaches. This first part of the model is referred to as the "site choice" model in the following discussions.

The model is called a "conditional" logit model because the choice of sites is conditional on knowing the total number of visits that the individual takes. Hence, the second part of the model explains the total

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[a] See Domenich and McFadden (1975) for an authoritative treatment of this model.

number of visits an individual makes to <u>any</u> of the study beaches. This
second part of the model is referred to as the "visitation" model.

The overall structure of the model can be summarized as follows. The
number of visits by individual i to beach j is n_{ij}. The individual makes a
total Of n_i beach visits during the summer. The probability of an
individual i going to beach j (or the proportion of her/his total beach
visits which are made to beach j) is p_{ij}. Then we model the number of
visits to beach j by individual i as:

$$n_{ij} = n_i \, p_{ij} \qquad \qquad (6.1)$$

We estimate n_i in the visitation model and p_{ij} in the site choice model
and predict n_{ij} using this equation.

For the site choice model, the dependent variable is the probability of
visiting a given beach. While this variable is precisely the probability Of
visiting a certain beach, it can also be considered the proportion of the
time that an individual will go to a particular beach when she/he goes to the
beach at all. The probability of visiting a certain beach (given that a trip
is taken) is assumed to be a function of the desirability of that beach. We
take desirability to depend on the characteristics of the beach (e.g., water
quality), the travel cost/time associated with a visit to that beach, and the
socioeconomic characteristics of the invididual who is making the trip.
Through the procedures described in Appendix B, the probability of visiting a
beach is estimated as a linear function of these variables. The results for
the site choice model which are presented below can be interpreted much as
one would interpret an ordinary linear regression.

The dependent variable for the visitation model is the number of visits an individual made to any of the study area beaches during the summer. We assume that the total number of beach visits an individual takes is related to the socioeconomic characteristic of the individual and the overall desirability of the sites available to her/him. While there are many ways this latter variable might be measured, the details of constructing the conditional logit model require that it be derived from the site choice model in a specific way. This variable, called the "inclusive price", measures the average desirability of the available sites. Here, the term desirability has the same meaning as it did in the description of the site choice model and includes the level of water quality at each of the beaches. Through the inclusive price term in the visitation model, a change in water quality at one or more beaches will not only affect the split of visits among the various beaches, but will also affect the total number of beach visits which will be taken.

Linking together the site choice model, the visitation model, and Equation 6.1 permits one to model how changes in water quality at any of the sites will affect total number of visits to each of the sites. To simulate the effect of a change in water quality at one or more of the sites, we use the visitation model to predict total number of visits after the change in water quality, the site choice model to predict the fraction of the visits which will be made to each site, and Equation 6.1 to determine the number of visits made to each site.

In general, the benefits associated with a simulated improvement in water quality come from two sources: an increase in the total number of visits and an increase in the value of each of the visits. Of course, because the

demand model includes the interaction among beaches, a water quality improve-
ment at one beach might lead to a decrease in use at some other beach.   All
of these shifts in usage are included in our benefits calculations.

   Conceptually, we are interested in determining the <u>equivalent variation</u>.
Suppose we improve water quality at some set of beaches.   The equivalent
variation is the amount of income we would have to take away from an
individual to make her/him indifferent between the situation with higher
income/lower water quality and that with lower income/higher water quality.
The equivalent variation measures this willingness of an individual to pay
for an improvement in water quality.   This measure of benefit is a good
approximation to other measures of benefit (Willig, 1976 and 1978) and also
is of interest in its own right.

   Because income is not explicitly incorporated in the demand model, the
equivalent variation cannot be estimated directly. We use a modification of
a procedure developed by Small and Rosen (1982) and adapted to this problem
by Feenberg and Mills (1980) to determine the equivalent variation associated
with a change in water quality. The details of the procedure are presented
in Appendix B.4, but the method can be outlined as follows. Demand is a
function of travel distance and water quality. In the estimated demand
model, then, we know how an individual trades off travel distance and water
quality. We can estimate the value of a simulated improvement in water
quality by asking how much further could the individual travel given the
water quality improvement and be no worse off than she/he was before the
water quality improvement took place. Benefits are measured in units of
distance. Therefore, in order to put benefits in dollar units, we need to
know the cost per unit distance.

   Here we take cost to have two components: a money cost and a time cost.
It is important to discuss how time should enter the model. Because time is
a scarce resource which the recreationist must allocate, the amount of time
spent in travel and on the site itself should be included in the model.
Failure to do so will lead to an underestimate of the value of the site.
Unfortunately, the data available for this study does not permit usable
estimates of the effect of these two time variables. The survey data on time
spent on the site contained numerous missing observations. Further, it is
not conceptually clear how to measure the amount of time which would be spent
on sites not visited. Thought of in another way, we need to estimate a three
part model--site choice, visitation and time spent on site--and the data are
not adequate to do so. Attempts to include travel time along with distance
in the model failed because of the high collinearity between the two
variables.

   An alternative procedure was employed to partially account for the value
of time. Cesario (1976) suggested that the value of travel time for
recreation is about one third the wage rate. Consequently, our estimates of
welfare change were converted to money values of the basis of $0.12/mile (the
national average in 1974) plus travel time valued at one-third the
individual's wage rate.

   The wage rate was computed from information on income and the number of
days worked per year. From the household survey, we know the number of days
taken off per week, the number of holidays per year and the annual amount of
vacation time. By subtracting the sum of these figures from 365 days, we
know the number of days worked per year. Annual income is divided by the
number of working days to determine the average daily wage. Daily wage is
converted to an hourly wage assuming eight hours per work day.

6.2.2.3 <u>Model Results</u>

The recreation demand analysis provides several kinds of results. First, we present the estimates of the site choice and visitation models. These results are compared with those of Feenberg and Mills (1980) to show the effect of our different and, in our view, better measures of travel costs and water quality. Second, we use the procedures, outlined above and detailed in Appendix B.4, to simulate the effect of changes in water quality on recreation patterns and to estimate the recreation benefits of several specific water quality improvement scenarios for the Boston Harbor study area. These results depict total benefit curves for each of the water quality improvement scenarios.

Table 6-4 presents the estimates of the model parameters. The model, using all 467 cases, predicts the site choice correctly in 15.9 percent of the cases compared with 34.7 percent for the Feenberg-Mills model. We attribute this difference primarily to the fact that Feenberg and Mills grouped individuals according to residential (origin) location, which we did not. In addition, our specification of the site choice model omits several interaction terms (age x distance, income x distance). We felt that there was no good <u>a priori</u> rationale for including these interaction terms. The distance coefficient for the Feenberg-Mills model is about 0.33 expressed in one-way miles and evaluated at the mean of the interaction terms. This is more than three times higher than the value we obtained indicating the magnitude of the error from using straight line distance to proxy for actual travel distance in an urban area.

There are several other interesting differences in the two models which can be seen in the simulation results. A 10 percent reduction in coliform

Table 6-4.   Conditional Logit Model Estimates

Site Choice:	coefficient	t
Distance (miles one way)	-0.1003	-50.71
Water Temperature (°F)	-0.4088	-41.17
Fresh water (dummy)	-1.607	-27.79
Fecal Coliform (median)	-0.01275	-18.47
	At Convergence	At Zero
log likelihood (x10^5)	-0.1443	-0.1658
percent correctly predicted	15.9	3.5

Visitation	coefficient	t
Intercept	172.7	--
Inclusive Price	5.757	3.26
Age (years)	-0.3095	4.12
Education (years)	-0.5758	1.68
Income ($1974 x10^3)	0.2550	2.31

$$R^2 = 0.078$$
$$f\ (4,462) = 9.79$$

Note: Parameter estimates for the site choice model were obtained using QUAIL Version 3.5.

Source: Model developed and run by Clark Binkley, Yale University, School of Forestry and Environmental Sciences.

levels can be accompanied by an increase in two way travel distance of 0.254 miles and leave the individual's utility level unchanged. In the Feenberg-Mills model evaluated at the mean value of all the interaction terms, a 10 percent reduction in all water quality variables (total bacteria, oil, color) offsets an 0.5 mile increase in travel distance. It is curious that we find a negative value for the fresh water dummy variable, indicating Bostonians prefer saltwater to fresh water beaches, where Feenberg and Mills report a positive value. In sum, our model, using better travel cost and water quality data for a larger sample of individuals, seems to be more sensitive to water quality and less sensitive to distance than is the Feenberg-Mills model.

6.2.2.4 Benefit Estimates

The model presented above can be used to obtain estimates of the benefits of water quality improvement. Recall that the benefit measure we use is the equivalent variation measured in units of distance. These units are converted to units of dollars at the rate of $0.12/mile for travel costs plus an amount which reflects the time cost of travel: travel time valued at one-third the individual's wage rate. Travel time was determined from the CTPS study mentioned above. The wage rate was computed from information on income and the number of days worked per year as was described above. These per mile figures were doubled to reflect the fact that the demand model was estimated on one-way rather than two-way distance.

Four sets of simulations were performed. In each case the fecal coliform level at a single beach or group of beaches in the Boston Harbor Study area was decreased in increments of 10 percent up to a 90 percent improvement in water quality. These simulations map out the total benefit curve for water

pollution abatement in the various segments of Boston Harbor. Sites 7 (Constitution Beach) and 15 (Wollaston Beach) were examined separately because of their importance to Boston Harbor-based recreation and because of their location within the harbor. Sites 8 - 14, the beaches in the Dorchester/Neponset Bay CSO planning areas, (south from Castle Island to Tenean Beach), were treated as a group in a third simulation. Finally, a simulation including all of the sites 7 - 15 was performed, with 10 percent less water quality improvement at site 7 than the others. This simulation shows the effect of a full water pollution abatement program for the Boston Harbor Study area.

The summary results from these simulations are given in Table 6-5. The entries in the table are benefits per person per year and the corresponding change in visits per person for a given pollution reduction. Thus, to get a value per visitor day for the site the per capita benefit is divided by the change in per capita visits. The value per visitor day for the different sites and pollution reduction levels ranges from $5.60 to $5.70 (in 1974 dollars) and is within the range of user-day values found in the literature (see Table B-3, Appendix B). Total benefits rise steadily with increasing levels of water quality improvement, and the curve continues to climb even as high levels of abatement are achieved. This results in a marginal benefit curve which curves upward rather than downward as is commonly assumed. This unusual result might stem from the fact that the demand model was estimated using data from beaches generally having water quality levels much less than the 80 to 90 percent levels imply.

Table 6-6 summarizes the change in per capita visits for each of the control options. Then, the increases in number of visits are derived by multiplying change in per capita visits by the 1980 Census Boston

Table 6-5. Per Capita Annual Benefit Estimates from

Conditional Logit Model a/

($1974/capita/year)

	SITES			
	7 Constitution	8 - 1 4 Dorchester	15 Wollaston	7-15 b/ All
Value per visitor day c/	5.62	5.62	5.69	5.65
Equivalent 1982 dollars	11.00	11.00	11.14	11.06
% Reduction in Water Pollution				
10	.0340 (.006054)	.1562 (.02779)	.1176 (.02069)	.2731 (.04835)
20	.0687 (.01222)	.3240 (.05765)	.2469 (.0434)	.6614 (.1065)
30	.1040 (.01851)	.5055 (.08995)	.3889 (.06837)	.9539 (.1689)
40	.1400 (.02491)	.7030 (.1251)	.5446 (.09575)	1.334 (.2361)
50	.1766 (.03143)	.9192 (.1636)	.7155 (.1258)	1.744 (.3087)
60	.2140 (.03807)	1.158 (.2060)	.9027 (.1587)	2.189 (.3874)
70	.2521 (.04481)	1.422 (.2530)	1.108 (.1947)	2.672 (.4729)
80	.2908 (.05174)	1.718 (.3056)	1.332 (.2342)	3.199 (.5661)
90	-- --	2.050 (.3646)	1.577 (.2773)	3.774 (.6680)

a/ Change in per capita visits for given change in pollution is in parentheses.

b/ Reduction at site 7 is 10 percent less than reduction at site 8-15 (i.e., the first entry is a 10 percent reduction at 8-15 and no reduction at 7).

c/ Calculated by dividing $/capita/year by change in per capita visits and averaged over all percent pollution reduction simulations.

Note: For location of sites see map (Figure 6-1).

Table 6-6.   Increased Participation Estimates from Conditional Logit Model

Site No.	Beach	CSO	Ocean Outfall	Secondary Treatment	CSO plus Ocean Outfall	CSO plus Secondary Treatment
		Percent Pollution Abatement [a]				
7	Constitution	70	10	5	80	75
8-14	Dorchester/ Neponset	80	10	10	90	90
15	Wollaston	80	10	10	90	90
7-15	All Sites	70/80	10	5/10	80/90	75/90
		Increase in Per Capita Visits [b]				
7	Constitution	.0448	.0061	.003	.0517	.048
8-14	Dorchester/ Neponset	.3056	.0278	.0278	.3646	.3646
15	Wollaston	.2342	.0207	.0207	.2773	.2773
7-15	All Sites	.5661	.0484	.0484	.6680	.6171
		Lower Bound Increase in Number of Visits [c]				
7	Constitution	82,821	11,277	5,546	95,577	88,737
8-14	Dorchester/ Neponset	564,958	51,393	51,393	674,031	674,031
15	Wollaston	432,962	38,267	38,267	512,641	512,641
7-15	All Sites	1,046,541	89,477	89,477	1,234,922	1,140,824
		Upper Bound Increase in Number of Visits [d]				
7	Constitution	123,798	16,856	8,290	142,866	132,641
8-14	Dorchester/ Neponset	844,482	76,821	76,821	1,007,520	1,007,520
15	Wollaston	647,178	57,201	57,201	766,279	766,279
7-15	All Sites	1,564,336	133,747	133,747	1,845,922	1,705,268

[a] From Table 4-3.

[b] Based on Table 6-5.

[c] Derived by multiplying per capita increase by entire 1980 Boston SMSA population of 2,763,357 by reduction factor in Appendix B.3.

[d] Derived by multiplying per capita increase by entire 1980 Boston SMSA population of 2,763,357.

SMSA population. The value of increased visits can be calculated by multiplying increased visits by the consumer surplus per visit. These are presented in Table 6-7. Not surprisingly, these annual benefits are high. This is the result of both the large number of beach users and the large estimated percentage reduction in pollution.

6.2.2.5 Limits of Analysis

The principle theoretical shortcoming of this conditional logit approach is the link between objective water quality parameters and the subjective Perception by recreationists of water quality. Some water quality parameters (e.g., dissolved oxygen) are not easily perceived by recreationists and, consequently, an improvement in water quality (i.e., an increase in DO levels in the water) may not be perceived by recreationists, and their behavior (i.e., frequency of visits to the site) may not change.

This is not likely to be the case for the beaches in the Boston Harbor study area. Dornbusch's study (1975) found that floating debris and oil and grease were the most frequently perceived water quality indicators applicable to the logit, travel cost model as applied here. The presence of high fecal coliform counts, the water quality parameter used in this study, is highly correlated to oil and grease measures (Hanemann, 1978), parameters which are perceived by recreationists. Thus, the concern that recreation behavior is governed by perception and, ideally, the predicted changes in behavior be linked to water quality parameters that are perceived by recreationists has been addressed in this application of the logit model by using fecal coliform, instead of dissolved oxygen , as the water quality variable.

Table 6-7. Annual Benefit Estimates from
Conditional Logit Model (1982 $000)

Site No.	Beach	CSO	Ocean Outfall	Secondary Treatment	CSO plus Ocean Outfall	CSO plus Secondary Treatment
				LOWER BOUND ESTIMATES		
7	Constitution	911.0	124.0	61.0	1,051.3	976.1
8-14	Dorchester/ Neponset	6,214.5	565.3	565.3	7,414.3	7,414.3
15	Wollaston	4,823.2	426.3	426.3	5,710.8	5,710.8
7-15	All Sites	11,574.7	989.6	989.6	13,658.2	12,617.5
				UPPER BOUND ESTIMATES		
7	Constitution	1,361.8	185.4	91.2	1,571.2	1,459.1
8-14	Dorchester/ Neponset	9,289.3	845.0	845.0	11,082.7	11,082.7
15	Wollaston	7,209.6	637.2	637.2	8,536.3	8,536.3
7-15	All Sites	17,301.6	1,479.2	1,479.2	20,451.9	18,860.3

Source: Derived by multiplying $1982 value per visitor day from Table 6-6
by increase in number of visits.

An additional shortcoming of this conditional logit approach is the use of travel costs to simulate prices. Travel costs may be difficult to specify because travel may have a special utility or disutility in itself, based on aesthetics of the travel route and travel time, in addition to travel costs. The improved water quality data, the incorporation of travel time, and the estimation of travel distance, and the estimation of consumer surplus, however, make the logit model the most empirically and theoretically sound of all the methodologies used to estimate swimming benefits from improving water quality in Boston Harbor.

Despite these limitations, the benefit estimates resulting from the logit model are instructive in two ways. The difference in the estimates of increase in demand as measured by user days using the logit technique (Table 6-6) as opposed to the increased participation technique (Table 6-2) depend on the treatment option and the beach location. The logit model predicts greater participation for the STP options (ocean outfall and secondary treatment) and less participation under the CSO and CSO and STP combined options than does the increased participation approach. For the individual beaches the logit model predicts greater participation at Dorchester/Neponset and Constitution while less participation at Wollaston. The predicted increased days for the logit model are within the bounds of seasonal capacity as estimated above (see Section 6.1.1). The other factors, such as crowding, adequate parking and presence of jellyfish, however, have unknown impacts as was noted above for the increased participation approach. In addition, the average value per visitor day determined by the logit model--$11.06--is almost-twice as great as the moderate user day value of $5.80, indicating that applying a user-day value of that magnitude to estimate consumer surplus may seriously understate total benefits.

6.2.3 <u>Swimming--Beach Closings</u>

An alternative method for calculating swimming benefits from increased participation because of improved water quality is to determine the value Of lost participation if beaches are closed because of fecal contamination. Essentially, this technique estimates the dollar value of the number of daily beach closings by multiplying the average consumer surplus per daytrip (in dollars per unit) by the daily attendance at each beach and by the number Of daily beach closings due to water pollution.

The information needed to calculate these benefits using this technique is usually more readily available than detailed information required for benefit estimation using the previously described increased participaton technique, and thus this method has often formed the basis for calculating total swimming benefits. In the case of Boston Harbor beaches, different health standards are applied according to beach ownership, The MDC does not actually close beaches when fecal coliform measures are high enough to represent a health hazard, but they do post signs that the beaches are unsafe for swimming. Signs are posted at an MDC beach when fecal coliform counts exceed 500 MPN/100 ml. A few towns use a standard of 1,000 MPN/100 ml total coliform. Federal standards are the most strict, suggesting closure when fecal coliform counts exceed 200 MPN/100 ml.

The first step in this technique is to decide which health standard to apply. We have chosen to use the strict federal standard of 200 MPN/100 ml to establish an upper bound and the MDC standard of 500 MPN/100 ml as a lower bound. We did not choose the 1,000 MPN/100 ml as a lower bound because few of the affected town beaches use this level, and there are few times during the

season when coliform concentrations reach this high a level. We have also assumed that there is limited or no attendance at the beaches during the days when fecal coliform counts exceed the 200 MPN/100 ml and 500 MPN/100 ml levels.

The next step is to relate bacteriological contamination with daily attendance figures so that we can arrive at a number of lost recreation days. Unfortunately, as previously described, the only attendance figures available are seasonal (Memorial Day to labor Day) data, making it difficult to assess the exact number of swimmers affected by daily beach closings. There is also the added complication that weekend attendance at beaches is usually greater than weekday attendance and, therefore, weekend violations of water quality standards have a greater impact on potential losses than weekday violations. Data limitations prevented us from considering this effect. Instead we have assumed a direct proportional relationship between total seasonal attendance figures and percentage of times during the season that water quality levels exceed 200 MPN/100 ml and 500 MPN/100 ml. For example, if a beach has water quality levels which exceed 200 MPN/100 ml during five percent of the season, then we assume that five percent of total attendance will be affected and will not go to the beach (see Appendix B.5 for details). This assumption probably understates the case since water quality problems tend to be the worst during the hottest times of the year, when beach attendance is the highest,

6.2.3.1 Boston Harbor Beaches

In order to arrive at savings according to the CSO and STP options, it is necessary to multiply these base visits by the predicted percent cleanup. These base-case lost visits and their corresponding averted lost visits due to pollution control programs are presented at the top of Tables 6-8

and 6-9.   The final step in this methodology is to value these averted lost attendance days by applying a range of user-day dollar values.   These values represent the savings due to averted beach closings due to pollution abatement in Boston Harbor and are presented at the bottom of Tables 6-8 and 6-9.

6.2.3.2 Nantasket Beach

The only other swimming beach in our study area is Nantasket Beach.   It is expected to be adversely affected by the deep ocean outfall option (see Table. 4-3).   We have used only the beach closing method to estimate the effects on swimming at Nantasket Beach because of the limitations of available data and methodology for measuring effects of increases in pollutant levels.

Seasonal population at Nantasket Beach is estimated to be 3,035,000, based on information from Binkley and Hanemann (1975) and the MDC. Currently, Nantasket Beach has water quality levels which exceed 200 MPN/100 ml approximately 2.3 percent of the season. Water quality is expected to decrease by 10 percent from current levels if a deep ocean outfall is constructed.   It is difficult to predict the relationship between this percentage decrease in water quality and the corresponding percentage changes in pollutant concentrations exceeding 200 MPN/100 ml and 500 MPN/100 ml. We have chosen to conservatively assume that the water quality level at Nantasket will exceed 500 MPN/100 ml at least as frequently as it was exceeded at the 200 MPN/100 ml level, or 2.3 percent of the season. By multiplying the seasonal attendance estimates by this percentage, we arrive at a number of lost visits totalling 69,805.   These lost visits can be valued by applying a range of user day values from $1.60 to $11.06.   Thus, we arrive

Table 6-8. Annual Benefit of Averted Beach Closings
at 200 MPN/100 ml (1982 $000)

Beach	Number of Lost Visits a/	CSO	Ocean Outfall	Secondary Treatment	CSO plus Ocean Outfall	CSO plus Secondary Treatment
			Averted Lost Visits b/			
Constitution	29,019	20,313	2,902	1,451	23,215	21,764
Dorchester						
Castle Island	1,010	808	101	101	909	909
Pleasure Bay	11,779	9,423	1,178	1,178	10,601	10,601
Carson	6,604	5,283	660	660	5,943	5,943
Malibu	14,423	11,539	1,442	1,442	12,981	12,981
Tenean	41,519	33,215	4,152	4,152	37,367	37,367
Wollaston	518,870	415,096	51,887	51,887	46 6,983	466,983
Quincy	13,687	10,950	1,369	1,369	12,319	12,319
Weymouth	11,966	–	3,590	3,590	3,590.	3,590
Hingham	–	–	–	–	–	–
Hull	3,505	–	1,052	1,052	1,052	1,052
TOTAL	652,382	506,627	68,333	66,882	574,960	573,509

User Day Value	Annual Benefit of Averted Beach Closings c/ for All Boston Harbor Beaches (1982 $000)				
$ 1.60	810.6	109.3	107.0	876.7	860.0
$ 5.80	2,938.4	396.3	387.9	3,178.2	3,117.5
$11.06	5,603.3	755.7	739.7	6,060.4	5,994.8

a/ See Appendix B.5.
b/ Number of lost visits multiplied by percent pollution abatement (in Table 4-3).
c/ Total averted lost visits multiplied by user day value (in Table B-3, Appendix B).

Table 6-9. Annual Benefit of Averted Beach Closings
at 500 MPN/100 ml (1982 $000)

Beach	Number of Lost Visits a/	CSO	Ocean Outfall	Secondary Treatment	CSO plus Ocean Outfall	CSO plus Secondary Treatment
				Averted Lost Visits b/		
Constitution	11,606	8,124	1,161	580	9,285	8,704
Dorchester						
Castle Island	433	346	43	43	3 8 9	389
Pleasure Bay	5,049	4,039	505	505	4,544	4,544
Carson	4,714	3,771	471	471	4,242	4,242
Malibu	4,328	3,462	433	433	3,895	3,895
Tenean	24,107	19,286	2,411	2,411	21,697	21,697
Wollaston	25 9,435	207,548	25,944	25,944	23 3,492	233,492
Quincy	6,537	5,230	654	654	5,884	5,844
Weymouth	-	-	-	-	-	-
Hingham	-	-	-	-	-	-
Hull	3,505		1,052	1,052	1,052	1,052
TOTAL	319,714	251,806	32,674	32,093	284,480	283,899

User Day Value	Annual Benefit of Averted Beach Closings c/ for All Boston Harbor Beaches (1982 $000)				
$ 1.60	402.9	52.3	51.3	455.2	454.2
$ 5.80	1,460.5	189.5	186.1	1,650.0	1,646.6
$11.06	2,785.0	361.4	354.9	3,146.3	3,139.9

a/ See Appendix B.5.
b/ Number of lost visits multiplied by percent pollution abatement (in Table 4-3).
c/ Total averted lost visits multiplied by user day value (in Table B-3, Appendix B).

at a range of $111,688 to $772,043, which represents a conservative estimate Of swimming-related pollution costs at Nantasket Beach attributable to implementation of the deep ocean outfall option.

6.2.3.3 Benefit Estimates

It is clear that the greatest benefits will derive from cleaning up the Dorchester Bay and Wollaston Beaches because these are the areas with the greatest and most frequent water quality violations, and they are the most popular beaches. Tenean and Wollaston Beaches, especially, have the greatest number of averted lost visits. Based on the strict 200 MPN/100 ml standard, Wollaston has nearly 520,000 lost visits while Tenean has over 41,500.

Benefits to the STP-affected beaches of Weymouth, Hingham and Hull are extremely low for both the upper bound and lower bound case for a number of reasons. These include the fairly good quality of shoreline water, the fact that the STP pollution control programs are expected to reduce fecal coliform concentration and, thus, reduce beach closings, by only 30 percent, and the fact that attendance is low at these beaches.

6.2.3.4 Limits of Analysis

These dollar benefits are significantly lower than the values calculated for swimming benefits using the increased participation methodology, previously described. The reasons for this difference are many and only serve to emphasize the many limitations and shortcomings of using this methodology to estimate recreation benefits. Normally, beach closings are calculated by relating the intensity of rain events to CSO overflow and the corresponding effect on ambient water quality and beach attendance. This methodology was not utilized, however, because of data limitations and

because a substantial portion of ambient water quality problems in beach areas in Boston Harbor stems from problems with dry weather overflow (DWO). The beach closing methodology attempts to capture the general seasonal relationship between CSO/DWO events and beach participation based on seasonal averages of ambient water quality and estimates of seasonal beach attendance. It underestimates total swimming benefits because it cannot capture the dollar value of increased number of visits due to cleaner and more attractive beaches, nor can it capture the increase in willingness to pay for safer and cleaner bathing areas. In addition, these estimates for Boston Harbor are based on the assumption that there is a direct correlation between percent fecal contamination and percent beach closings. In reality, this relationship may not be directly proportional and, in fact, there may not be a significant relationship between the two parameters. We can only conclude that this methodology seriously underestimates swimming-related benefits, and that this range of values is a less appropriate measure of water pollution abatement benefits than values derived from previously described techniques.

6.3 Recreational Boating

One of the significant consumer surplus benefits associated with water pollution abatement in Boston Harbor is the increased use and utility of harbor waters by boaters, and the savings in dollars spent on these activities. Unfortunately, unlike the previously described swimming-related benefits, there is little available information upon which to base these benefits. Instead we make only very general estimates of consumer surplus using a number of assumptions about increased participation and the corresponding value of these increases and applying aggregated information from regional and federal recreation studies.

6.3.1 <u>Increased Participation</u>

It has been well documented that improved water quality can have an important effect on the level of recreational boating (Davidson, Adams and Seneca, 1966). Participation in all boating activities in Boston Harbor--sailing, motor boating, canoeing and windsurfing--is expected to increase with corresponding decreases in water pollutant levels. Benefits from this improvement stem from an increase in frequency of participation by previous users, willingness to pay a higher price for the boating experience because of improved water quality , and new participation by previous non-users. Much of this increased participation is likely to come from increases in the aesthetic boating experience due to the decreased offensiveness of presently polluted areas, especially those areas directly surrounding the sewage treatment plants and near CSO outfalls. Improvements to CSOs in Dorchester Bay and the Deer and Nut Island STPs will most definitely improve water quality and, thereby, encourage increased recreational boating in these areas. Unfortunately, there are few boating participation studies which link a change in water quality to a change in boater use of water resources which are applicable to Boston Harbor and, thus, recreation participation data on present use, along with data on unmet demand, was used to estimate boating benefits from improvements in water quality.

We have used a benefit estimation methodology which is similar to the increased participation technique described for swimming related benefits. Using data from a variety of recreational sources we have estimated the number of user days per year for two categories of boating--motor boating and sailing. Although there are no quantitative measures of predicted percentage increases in boating that are expected to occur under the various CSO and STP

options, we can estimate this increased participation by assuming that
cleaner waters will supply a portion of unmet (latent) demand. Two of the
recreational studies have estimated a 45-69 percent unmet demand in the
Boston Metropolitan area for boating. This translates into a need of 1.8 to
2.8 million days for motor boating and 0.8 to 1.3 million days for sailing.
We can assume that some of this demand will be met by cleaning up harbor
waters, although it is not immediately clear what percentage will actually be
met. Because fishing and boating take place throughout the harbor and are
not restricted to certain areas we have calculated these benefits on a
harbor-wide basis for the two combined options, CSO plus Ocean Outfall and
GO plus Secondary Treatment. We have assumed that abating pollution from
CSO and Ocean Outfall controls will lead to a 2 to 10 percent reduction in
unmet demand. We assumed the GO plus Secondary Treatment option would meet
5 to 12 percent of unmet demand. The lower figures for the deep ocean
outfall option reflect the adverse impact this option is expected to have on
the area around the Brewsters Islands.

Although these figures night appear to be overly conservative, we have
chosen them for two reasons. First, we believe that the latent demand of
45-69 percent reported in the recreational studies is probably an
overestimate (and have chosen to use 50% in our calculations). Second, even
though more boaters might increase their use of Boston Harbor when pollution
is decreased, there is a limited supply of available marinas, boatyards and
docks. Thus, for every ten new boaters who might want to use the harbor,
only one might actually be able to because of limited facilities. In other
words, we have assumed that the binding constraint on increases in boating

participation is not only poor water quality, but the supply of boating

facilities as well. This has been demonstrated by Davidson et al. (1966) who

determined that the supply of boatable water is affected by the depth, width,

access, and quality of a water resource. In this study the upper bound

benefit estimate is determined by the facility availability constraint.

6.3.2 Benefits Estimates

Using these assumed recreational figures, it is possible to calculate the

number of increased boating days. By applying a lower bound user day value

of $18.14 and an upper bound value of $45.19 (see Table B-3, Appendix B) to

the range of increased boating days, we arrive at the estimated value of

benefits for boating activities (see Table 6-10).

6.3.3 Limits of Analysis

Calculation of boating-related benefits is limited by both methodology

and data base. Statistics on use and participation were inconsistent among

all sources, requiring us to judge which statistics were the most appropriate

for a given step in the estimation process. There was scant information on

latent demand, requiring us to use a possibly overstated estimate from a

Boston-based study. Benefit estimation was further compromised by having to

assume what percentage of latent demand was met by cleaning up harbor waters,

a prediction based on professional judgment rather than quantitative

information. All of these shortcomings are reflected in the final benefit

values. In addition, this benefit methodology does not capture total consumer

surplus in that only the benefits of water quality improvement to new

participants, and not increased utility and increased participation of

Table 6-10. Annual Saltwater Boating Benefits
(1982$)

	Motor Boating	Sailing	Total
LATENT DEMAND			
% of SMSA	22	15	
# of recreators	607,938	414,504	1,022,442
User Days per Participant	6.7	4.5	
# of User Days	4,073,185	1,865,268	5,938,453
Latent Demand (50%)	2,036,593	932,634	2,969,226
LOWER BOUND ESTIMATES			
% Latent Demand met by			
CSOs and Ocean Outfall	2	2	2
CSOs and Secondary Treatment	5	5	5
Days of Latent Demand met by			
CSOs and Ocean Outfall	40,732	18,653	59,385
CSOs and Secondary Treatment	101,830	46,632	148,462
Annual Benefits (User Day Value = $18.14[a])			
CSOs and Ocean Outfall	3,694,000	1,692,000	5,386,000
CSOs and Secondary Treatment	4,433,000	2,030,000	6,463,000
UPPER BOUND ESTIMATES			
% Latent Demand met by			
CSOs and Ocean Outfall	10	10	10
CSOs, and Secondary Treatment	12	12	12
Days of Latent Demand met by			
CSOs and Ocean Outfall	203,659	9 3,263	296,192
CSOs and Secondary	244,391	111,916	356,307
Annual Benefits (User Day Value = $40.89[a])			
CSOs and Ocean Outfall	8,328,000	3,814,000	12,129,000
CSOs and Secondary Treatment	9,993,000	4,576,000	14,569,000

[a]/See Table B-3, Appendix B.

previous users, is measured. These benefit values also understate total

boating-related benefits because other boating activities, such as canoeing

and windsurfing, have not been considered and because reductions in the

amount of fouling of boats and equipment have not been considered. Finally,

although boating benefits are substantial when estimated for the entire study

area in the Boston Harbor, data limitations prevented disaggregating these

benefits to the level of the areas specifically affected by the pollution

abatement options. Thus, these benefit estimates can only be used to

emphasize the relative importance of the effect of improved water quality on

recreational boating and to underscore the conclusion that these effects are

both monetizable and significant.

6.4 Recreational Fishing

   The benefits to recreational fishing of improving water quality in Boston

Harbor has two components. First, cleaner water will affect the availability

of fish, both species and numbers. Second, this change in fish availability

will affect fishing participation rates. In addition, there may be a

 "perception" effect on fishing activity which is independent of this

availability, implying a more positive response towards fishing in cleaner

water.[a] The consumer surplus from improving water quality should, thus,

be measured by calculating increases in participation stemming from changes

 in fish species and numbers and the increased utility or willingness to pay a

higher price to fish in cleaner water.

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   [a] An informal survey by Metcalf and Eddy (1982) reported that, although
in general it did not appear that fishers avoided discharge areas, one bait
shop owner had reported that the Nut Island discharge made the area
unattractive for his clients. In another, larger, survey conducted by the
Massachusetts Division of Marine Fisheries (1982) , concern was expressed over
the effects of pollution by toxic chemicals and sewage waste (65-60 percent
felt these were serious problems), loss of fish habitat (57 percent),
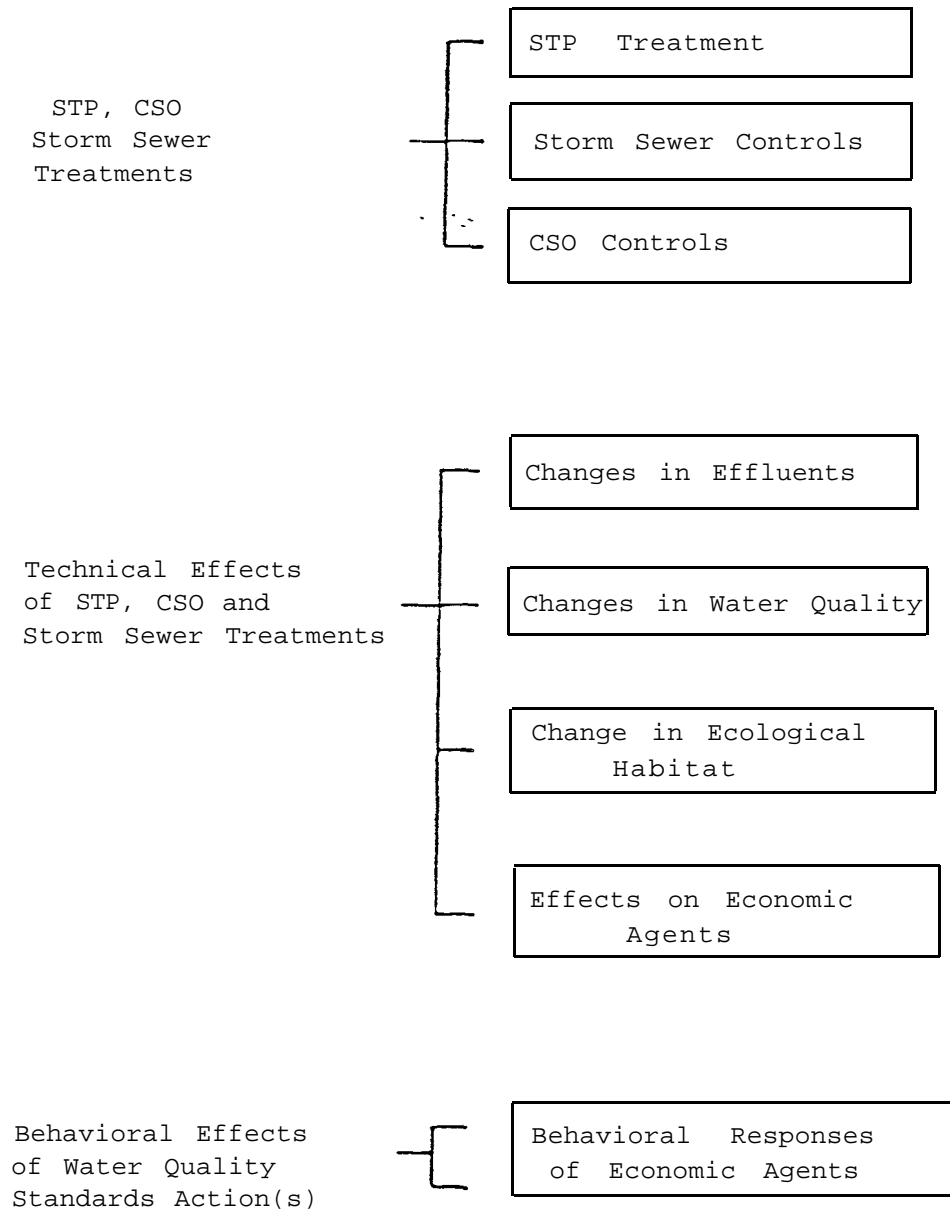adequate stocks of fish to catch (43 percent).

6.4.1 Components of Recreational Fishing

Calculating this fishing-related consumer surplus is difficult however, because it involves assessing the technical effects/impacts of the pollution control actions, including changes in ecological habitat, as well as determining the behavioral effect of these actions. These steps are summarized in Figure 6-2.

A number of studies have attempted to model and analyze the effects and responses of fish and anglers to changes in water quality from pollution control programs. Bell and Canterbery (1976) modeled biological production functions of important recreational fish and applied them to recreational fisheries data to arrive at estimates of recreational fishing benefits for each state in the Union. We have chosen not to apply their results to the study area because of methodological and data limitations. One other study (Russell and Vaughan, 1982) developed a model to estimate the probability of being an angler, the probability of spending time to fish, and the average length of time for each type of fishing. Their model estimates the effects of water quality changes on number of fishing sites, types of supportable fish population, and change in aesthetic experience. This model can only be used for freshwater fishing areas and, thus, cannot be applied to the Boston Harbor Study area.

It was not possible to calculate many of the effects and responses listed in Figure 6-2, which is a prerequisite to calculating measures of consumer surplus. It was particularly difficult to determine how pollution control plan-effluents would precisely affect or change the ecological habitats of important recreational fish. tie preferred summer recreational fish in the harbor is winter flounder (Pseudopleuronectes americanus) although other

Figure 6-2. Effects and Responses to STP, CSO and
Sewer Controls

STP, CSO
Storm Sewer
Treatments

> STP Treatment

> Storm Sewer Controls

> CSO Controls

Technical Effects
of STP, CSO and
Storm Sewer Treatments

> Changes in Effluents

> Changes in Water Quality

> Change in Ecological
Habitat

> Effects on Economic
Agents

Behavioral Effects
of Water Quality
Standards Action(s)

> Behavioral Responses
of Economic Agents

desirable species include striped bass (<u>Morone</u> <u>saxatilis</u>), bluefish
 (<u>Pomatomu</u>s <u>saltatrix</u>), and cod (<u>Gadus</u> <u>morhua</u>). Winter flounder appears to be
the only species definitely affected by Harbor pollution, preferring the more
organically polluted areas to the cleaner ones. Despite this attraction to
polluted areas it was not possible to link these changes with the specific
pollution control options. In general, productivity throughout the Boston
Harbor Study area is expected to increase with corresponding decreases in
water pollutants, although we were not able to quantitatively determine the
increase in productivity. These data limitations required us to apply a
general participation approach to estimate fishing benefits, similar to the
method previously described under boating benefits.

   Recreation studies provided information on percentage participation,
value of user days, and total user days per year for marine fishing. We were
unable to find direct, reliable figures on latent demand and, thus, we
assumed a rate identical to that used for boating. We applied a user day
value of from $12.90 to $28.46 per user-day derived from a number of studies
presented in Table B-3, Appendix B.   tie results are presented in Table 6-11.

6.4.2 <u>Benefits Estimates</u>

   Fishing benefits can only be estimated for the entire Boston Harbor Study
area, rather than for each distinct geographical area. The possibility of
double counting some boaters who primarily fish from their boats exists.
However, no information was available to suggest how prevalent this kind of
behavior might be. For this reason, these benefit figures should be
interpreted with caution.

Table 6-11. Annual Recreational Fishing Benefits
(1982$)

	Lower Bound	Upper Bound
Latent Demand		
% of SMSA	7	14
# of recreators	193,435	386,810
User Days per Participant	12	12
# of User Days	2,321,220	4,642,440
Latent Demand (50%)	1,160,610	2,321,220
% of Latent Demand met by		
CSOs and Ocean Outfall	2	10
CSOs and Secondary Treatment	5	12
Days of Latent Demand met by		
CSOs and Ocean Outfall	23,212	232,122
CSOs and Secondary Treatment	58,030	278,546
User Day Value a/	$12.89	$34.08
Annual Benefit Value		
CSOs and Ocean Outfall	299,000	7,911,000
CSOs and Secondary Treatment	749,000	9,493,000

a/ See Table B-3, Appendix B

6.4.3 <u>Limits of Analysis</u>

Estimation of recreational fishing benefits is limited by methodology and data base in ways similar to those described under boating benefits. A major limitation of this analysis is the lack of information linking changes in water quality to corresponding changes in both biological habit and fish population. This lack of data prevented a precise estimation of the effects of availability and number of fish species on fishing participation. Another problem was that the available recreation fishing statistics on participation and unmet demand were often inconsistent, requiring us to judge which were the most appropriate for a given step in the estimation process. Another limitation of the analysis is that the methodology used here does not capture all components of consumer surplus. Benefit values reflect only benefits to new participants, and not the value of increased utility or increase in participation by previous users. The last limitation of this analysis is the possibility of some double counting of fishing and boating benefits. Thus, these estimates can only be used to emphasize the importance of the effect of improved water quality on recreational fishing.

6.5 <u>Boston Harbor Islands</u>

The Boston Harbor Islands are a unique natural resource in a metropolitan area which possesses only half of the recommended minimum acreage of open space per thousand population. The Islands are predominantly open, natural areas which offer a wide range of activities such as swimming, boating, fishing, hiking, picknicking , camping and historic sight-seeing. Most of the islands have limited recreational facilities, which restrict current and potential visits. However, effluent from the two sewage treatment plants

seriously degrades water quality around the islands, also discouraging recreation.   Assuming that the planned recreational facilites were constructed, then improving water quality around the islands would lead to a corresponding increase in both frequency of participation and total number of visitors.   It is possible to roughly estimate this increased participation, despite scarce recreational data.

6.5.1 Increased Participation

Recreational data from the Boston Harbor Islands Comprehensive Plan, (Metropolitan Planning Council, 1972) suggests that current attendance at all the Islands for all recreational activities is 265,000 per season and that total capacity, assuming the planned structural improvements and additions are implemented, is 560,000 per season.   This results in an excess supply of 295,000 visits per season.   Given the unique nature of the Harbor Islands, we have assumed that some of the latent demand for recreation in the harbor--especially swimming, boating and fishing--could be met largely by improving water quality around the Islands.   Implementation of either of the STP options is expected to improve the water quality around the nearest Harbor Islands.   However, implementation of the deep ocean outfall option is expected to have adverse effects on the Brewsters Islands, which are the outermost islands of Boston Harbor.   The Brewsters include Great Brewster, Middle Brewster, Outer Brewster, Calf, Little Calf and Green Islands, Shag Rocks, and the Graves.   These islands constitute one of the most unique marine environments on the Massachusetts coast , providing a highly accessible marine habitat, conservation areas , and excellent sites for recreational diving.   Water quality is expected to decrease by 10 to 15 percent in the area surrounding these islands because they are so close to the ocean outfall

diffuser. Consequently, many of the recreational activities such as diving, swimming, boating and hiking will be affected by this degradation of water quality.

To develop benefit estimates for recreational activities at the Harbor Islands we have assumed a percentage increase (decrease) in visits and applied a range of previously utilized user day values. The assumptions and calculations of these benefit values are presented in Table 6-12.

6.5.2 Limits of Analysis

The previously described methodology is limited by both its data bases and its assumptions. There is little available information on latent demand for the Boston Harbor Islands and, thus, we had to assume an upper and lower bound participation rate. Although there are accurate estimates for current Harbor Island attendance, capacity estimates should be interpreted and used with caution. The derived benefit estimates probably underestimate STP-related benefits for the Islands because the applied methodology cannot, theoretically, capture either the dollar value of increased utility or the value of increases in frequency of participation. These benefit values should also be viewed as rough estimates because of the possibility of double-counting from other benefit categories such as boating and fishing for the entire harbor and because costs of upgrading recreational facilities, which are a necesary prerequisite to increased participation, have not been included.

6.6 Summary of Recreation Benefits

Reducing water pollution in the Boston Harbor Study area by implementing the different pollution control options will result in many recreation

Table 6-12. Annual Benefits for Recreation on Boston Harbor Islands

(1982 $000)

	Outer Harbor Islands	Brewsters Islands
Current Attendance	258,000	7,000
Capacity	546,000	14,000
Excess Supply (latent demand)	288,000	7,000
% Change in Water Quality		
Ocean Outfall Option	60 to 90	-10 to -15
Secondary Treatment Option	30 to 80	30 to 40
% of Latent Demand met by		
Ocean Outfall Option	50 to 90	-20 to -30
Secondary Treatment Option	50 to 75	50 to 75
Change in Visitor Days due to [a]		
Ocean Outfall Option	144,000 to 259,200	-1,400 to -2,100
Secondary Treatment Option	144,000 to 216,000	3,500 to 5,250
User Day Values [b]	$5.80 to $11.06	$5.80 to $11.06
Annual Benefit Values (1982 $000)		
Ocean Outfall Option	835 to 2,867	-8.1 to -23.2
Secondary Treatment Option	835 to 2,389	20.3 to 58.1

[a] Change in Visitor Days calculated by multiplying latent demand by the percentage of latent demand met by the different treatment options.

[b] See Table B-3, Appendix B.

benefits (see Table 6-13). A variety of methodologies have been used to calculate the range of these benefits. These include: (1) swimming--increased participation; (2) swimming--travel cost with conditional logit model; (3) swimming--beach closings; (4) boating and fishing--increased participation; (5) all recreation activities for Boston Harbor Islands--increased participation.

Recreation benefits as calculated by the travel cost method, are greatest in the category of swimming. Benefits associated with the CSO options are substantial while STP-related swimming benefits are minor, because the majority of swimming in the harbor study area takes place along shorelines, which are not as adversely affected by STPs. Fishing and boating benefits have been calculated only for the entire harbor and not for each treatment alternative, because of data limitations. Benefits for both these categories are also substantial while the greatest STP-related recreation benefits are from water quality improvements near the Boston Harbor Islands.

Table 6-13. Annual Recreation Benefits
(Thousands of 1982$)

Benefit	CSO	Ocean Outfall	Secondary Treatment	CSO plus Ocean Outfall	CSO plus Secondary Treatment
A. SWIMMING					
1. Increased participation					
a. Recreation studies a/					
High:	16,737	2,436	2,347	19,174	19,084
Low:	1,620	236	227	1,856	1,847
Moderate:	7,325	1,066	1,027	8,391	8,352
2. Increased Participation and Increased Utility of Visit					
a. Logit model: b/					
High:	17,302	1,479	1,479	20,416	18,860
Low:	11,575	990	990	13,658	12,618
Moderate:	14,439	1,235	1,235	17,037	15,739
3. Beach Closings					
a. Strict c/ 200MPN f.c.					
High:	5,603	756	740	6,060	5,945
Low	811	109	107	877	860
Moderate:	2,938	396	388	3,178	3,118
b. Lenient d/ 500 MPN f.c.					
High:	2,785	351	355	3,146	3,140
Low:	403	52	51	455	454
Moderate:	1,461	189	186	1,650	1,647
c. Nantasket Beach e/					
High:	0	(772)	0	(772)	0
Low:	0	(112)	0	(112)	0
Moderate:	0	(405)	0	(405)	0
B. BOATING f/ Increased Participation					
High:	NA	NA	NA	12,129	14,569
Low:	NA	NA	NA	5,386	6,463
Moderate:	NA	NA	NA	8,758	10,516
C. FISHING g/					
Increased Participation					
High:	NA	NA	NA	7,911	9,493
Low:	NA	NA	NA	299	749
Moderate:	NA	NA	NA	4,105	5,121
D. BOSTON HARBOR ISLANDS					
--Increased Participation h/					
High:	0	2,844	2,447	2,844	2,447
Low:	0	827	855	827	855
Moderate:	0	1,835	1,651	1,835	1,651

a/ From Table 6-3.
b/ From Table 6-7, does not include.
   Quincy town beaches.

e/ From Section 6.2.3.2;
   costs not benefits.
f/ From Table 6-10.

References

Abt Associates, 1979.   New York-New England Recreational Demand Study, Vol. I and II, Cambridge, MA

Bell, F.W. and E.R. Canterbery (1975). An Assessment of the Economic Benefits Which Will Accrue to Commercial and Recreational Fisheries from Incremental Improvements in the Quality of Coastal Waters, Florida State University, Tallahassee, FL.

Ben-Akiva, J., 1973.   The Structure of Passenger Travel Demand. MIT PhD. dissertation, Department of Civil Engineering.

Binkley, Clark S. and W. Michael Hanemann, 1975.   The Recreation Benefits of Water Quality Improvement.   U.S. Environmental Protection Agency, Washington, DC, NTIS PB257719.

Binkley, Clark S., 1977.   Estimating Recreation Benefits: Critical Review and Bibliography.   CPL Exchange Bibliography 1219.

Burt, Oscar R. and David Brewer, 1971.   Estimation of net social benefits from outdoor recreation. Econometrica.   pp 613-827 in Abel, Tihansky and Walsh, 1976, National Benefits of Water Pollution Control, Draft U.S. EPA Office of Research and Development, Washington, DC.

Cesario, F. J., 1976.   The Value of Time in Recreation Benefit Studies.   Land Economics, 52: 32-41.

Charbonneau, J. and J. Hay, 1978.   "Determinants and Economic Values of Hunting and Fishing."   Riper presented at the 43rd North American Wildlife and Natural Resource Conference.   Phoenix, Arizona.

Cicchetti, C., A. Fisher and V. K. Smith, 1976.   An Econometric Evaluation of a Generalized Consumer's Surplus Measure: the Mineral King Controversy. Econometrica, 44:   1253-1276.

Clawson, M. and J. H. Knetsch, 1966.   The Economics of Outdoor Recreation, Johns Hopkins University Press: Baltimore.

Davidson, P., G. Adams and J. Seneca, 1966.   The social value of water recreational facilities from an improvement in water quality: The Delaware Estuary, Water Research, Allen Kneese and Stephen C. Smith, eds., Baltimore: Johns Hopkins University Press for Resources for the Future, 1966.

Development Planning and Research Associates, Inc., 1976.   National Benefits of Achieving the 1977, 1983 and 1985 Water Quality Goals, U.S. EPA, Office of Research and Development, Washington, DC.

Dornbusch, David M., 1975.   The Impact of Water Quality Improvements on Residential Property Prices, National Commission on Water Quality, Washington, DC.

References

Ditton, R. and T. Goodale, 1972. <u>Marine Recreation Uses of Green Bay: A Study of Human Behavior and Attitude Patterns</u>, Technical Report No. 17, Sea Grant Program, University of Wisconsin, Madison.

Domenich, T. and Daniel McFadden, 1975. <u>Urban Travel Demand</u>. North Holland, Amsterdam.

Dwyer, John, John R. Kelly and Michael D. Bowes, 1977. <u>Improved Procedures for Valuation of the Contribution of Recreation to National Economic Development.</u> University of Illinois, Water Resources Center, Urbana, IL.

Ericson, Raymond, 1975. <u>Valuation of Water Quality in Outdoor Recreation</u>, PhD. Dissertation, Department of Economics, Colorado State University, Fort Collins, CO.

Feenberg, Daniel and Edwin Mills, 1980. <u>Measuring the Benefits of Water Pollution Abatement</u>, Academic Press, New York, NY.

<u>Federal Register</u>, Vol. 48, No. 48, March 10, 1983.

Hanemann, W. M., 1978. <u>A Methodological and Empirical Study of the Recreation Benefits from Water Quality Improvement.</u> PhD dissertation, Harvard University, Cambridge, MA

Heintz, H.T., A. Hershaft, and G.C. Horak, 1976. <u>National Damage of Air and Water Pollution</u>, U.S. Environmental Agency, Office of Research and Development, Washington, DC.

Massachusetts Department of Environmental Management, December, 1976. <u>Massachusetts Outdoors: Statewide Comprehensive Outdoor Recreation Plan (SCORP)</u>, Boston, MA.

Massachusetts Division of Marine Fisheries, 1982. <u>Massachusetts Marine Fisheries Management Report</u>, Boston, MA.

McFadden, D., 1973. Conditional Choice Logit Analysis of Qualitative Choice Behavior in P. Zarembka, ed. <u>Frontiers in Econometrics</u>, Academic Press, New York.

Metcalf and Eddy, 1975, <u>Eastern Massaschusetts Metropolitan Area Study (EMMA)</u>. Technical Data (Volume 13B), Socio-Economic Impact Analysis, Boston, MA.

Metcalf and Eddy, Inc.,1982. <u>Application for Modification of Secondary Treatment Requirements for its Deer Island and Nut Island Effluent Discharges into Marine Waters</u>, for Metropolitan District Commission, Boston, MA.

Metropolitan Planning Council, October 1972. <u>Boston Harbor Islands Comprehensive Plan</u>, for Massachusetts Department of Natural Resources, Boston, MA.

References

Morey, E.R., 1981. The Demand for Site-Specific Recreational Activities: A Characteristics Approach. J. Env. Econ. and Management, 8:345-371.

National Planning Association (NPA), 1975. Water-Related Recreation Benefits Resulting from Public Law 92-500. National Commission on Water Quality, Washington, DC.

Peterson, G., D. H. Anderson and D. W. Lime, 1983. Multiple-Use Site Demand Analysis: An Application to the Boundary Waters Canoe Area. J. Liesure Res. 14: 27-36.

Russell, C.S., and W.T. Vaughan, 1982. The national fishing benefits of water pollution control, Journal of Environmental Economics and Management, 9:328-353.

Small, K. and H. Rosen, 1981. Applied Welfare Economics with Discrete Choice Models. Econometrica 40: 105-130.

U.S. Department of Commerce, Bureau of the Census, 1982. 1980 Census of Population and Housing, Massachusetts. Washington, DC.

U.S. Department of Interior, March 1970. Outdoor Recreation Space Standards, Washington, DC.

U.S. Department of the Interior, 1982. 1980 Survey of Fishing, Hunting, and Wildlife Associated Recreation, Fish and Wildlife Service and U.S. Department of Commerce, Bureau of the Census, Washington, DC.

U.S. Department of the Interior, April 1984. The 1982-1983 Nationwide Recreation Survey, National Park Service, Washington, DC.

Willig, R., 1976. Consumer's Surplus without Apology. AER 66: 589-597.

Willig, R., 1978. Incremental Consumer's Surplus and Hedonic Price Adjustment. J. Econ. Theory 17:227-253.

Wilman, E., 1980. The Value of Time in Recreation Benefit Studies. J. Env. Econ. and Management 7: 272-286.

Section 7

Health Benefits

In order to assess the health benefits of reducing the level of pollution

in Boston Harbor, it is first necessary to understand the adverse effects

that such a level of pollution might have on users of Boston Harbor waters.

Until recently, most health effects associated with water have been estimated

for withdrawal uses for drinking water supplies rather than for instream

uses, such as swimming, or other withdrawal uses, such as fish consumption.

This focus, in part, has been due to what the public views as the more

serious nature of ingesting sewage contaminated water, but it has also been

affected by the relative ease of determining causal relationships between

water ingestion and illness as opposed to water contact and illness or the

less direct link of water pollutants to the food chain. Attempts to quantify

morbidity values and the corresponding benefits of decreasing the incidence

of illnesses contracted while swimming in polluted waters or consumption of

contaminated food have been made difficult by the lack of data on dose-

response and the corresponding population at risk.

This section focuses on two types of health benefits: swimming-related

illness and illness related to bacterial contamination of shellfish. Other

health risks, such as those due to the accumulation in the food chain of

heavy metals and toxics (e.g., copper, mercury, PCBs and silver found in the

tissues of lobsters and winter flounder), cannot be estimated because little

is known about how the accumulation takes place, the effects of consumption

or the dose response. Consequently, the benefits described in this section must be viewed as a partial analysis of the possible health benefits of improving water quality in the Boston Harbor.

7.1 Swimming-related Health Benefits

The method used to estimate swimming-related health benefits defines the population at risk and then applies a dose-response relationship. A discussion of the dose-response relationship used in this analysis is included below because this approach is a fairly recent development.

7.1.1 Benefit Measurement Approach

One of the dose-response data problems for water contact and disease is related to the indicators used to predict and quantify illness in the population. The conventional wisdom regarding public health and water borne disease assumes that since sewage contains fecal material and fecal material may contain pathogens, then the level of fecal material is an adequate measure of the potential for pathogens in the water. The parameter most commonly used as an indicator of the potential for pathogens is the fecal coliform bacterial count in the water column. Fecal coliforms are, in fact, an excellent indicator of the presence of domestic sewage, but they do not supply the kind of information needed to develop a dose-response relationship for swimming-related illnesses.

Recently, it has been established that the presence of another bacterial indicator, Enterococci, is a more accurate measure of water quality than fecal coliforms (Cabelli et al.,1980, 1982; Meiscier et al., 1982). This is principally due to the fact that Enterococci better mimic the aquatic behavior of the viruses responsible for the potentially most serious

(infectious hepatitis) and common (gastroenteritis) water-related enteric diseases.   In his 1980 and 1982 articles, Cabelli developed a dose-response relationship between Enterococci density and the number of cases of gastrointestinal symptoms per 1000 swimmers.

In order to apply this dose-response data to Boston Harbor beaches it was necessary to perform some preliminary calculations and transformations of the water quality data.   All of the water quality data for Boston area beaches is recorded in terms of concentrations of fecal and total coliforms, as required by local, state and federal health standards, rather than in concentrations of Enterococci.   Using Enterococci data gathered from local Boston beaches we developed a statistical relationship between the more available indicator, fecal coliform, and the more accurate indicator, Enterococci.   (See Appendix C for more details.)

Given the correspondence between fecal coliform and Enterococci and the dose-response relationship between Enterococci and gastrointestinal symptoms, it was possible to correlate water quality at affected beaches with potential swimming-related illness. Water quality data from 1974-1982 were collected and averaged for all Boston area beaches and a percentage range of fecal coliform concentrations was established. As described under the swimming/ beach closings section, population at risk was calculated by assuming proportional relationships between seasonal attendance figures and percent of time during the season that water quality levels fell into various ranges. For example, if fecal coliform standards fell between 30 and 50 MPN/100ml for two percent of the entire season at a beach, we assumed that two percent of the seasonal swimming population would be affected by this level of fecal

coliform.   In addition, we assumed that there were no swimmers among the visitors on days when fecal coliform counts were above 500 MPN/100 ml since this is the standard most of the towns and municipalities use for closing beaches or posting them as unsafe for swimming.

Given these different water quality levels and number of bathers at risk, we estimated the number of potential cases of gastrointestinal illness. These are presented in Table 7-1.   (See Appendix C for details of the calculation.) For a lower bound estimate of number of cases of illness, population at risk can be changed to reflect visitors to the beach who actually go swimming. If not all visitors to a beach go swimming, then not all visitors would be exposed to water pollution. The lower bound estimates of numbers of cases of illness reflect an estimate of 49% of all beach visitors actually go swimming. In addition, even with the improved water quality not all of the predicted increased visitors may go swimming because of air and water temperatures. During the 1982 and 1983 summer season, for example, over half of the days had water temperature below 65° F or air temperature below 75° F. For such days, some beach visitors may not go swimming. To take into account these relatively colder temperatures in the Boston Harbor area a factor based on the distribution of air and water temperatures is applied to reduce population at risk and, thus, the number of cases of illness. (See Appendix C.3 for derivation of population at-risk.)

The final stage in estimating swimming-related health benefits was to value these illnesses. Based on information from Cabelli et al. (1980), we have assumed that each case lasts from one to two days and requires sick leave from work but does not require medical treatment. We have applied a

Table 7-1. Annual Reduction in Cases of Gastrointestinal Illnesses

Beach	CSO Option	Ocean Outfall Option	Secondary Treatment Option	CSO Plus Ocean Outfall Option	CSO Plus Secondary Treatment Option
Constitution	161-596	21-79	11-39	248-919	200-741
Dorchester Bay					
Castle Island	21-77	2-7	2-7	28-103	28-103
Pleasure Bay	242-896	21-79	21-79	325-1203	325-1203
Carson	134-497	12-45	12-45	182-675	182-675
Malibu	198-735	18-68	18-68	285-1056	285-1056
Tenean	65-239	15-57	15-57	175-647	175-647
Wollaston	2419-8961	293-1085	293 -1085	4144-15348	4144-15348
Quincy	238-881	19-70	19-70	344-1275	344-1275
Weymouth	0	45-168	45-168	45-168	45-168
Hingham	0	9-35	9-35	9-35	9-35
Hull	0	27-100	27-100	27-100	27-100
Nantasket	0	(352)- (1302) *	0	(352)-(1302)*	0
Total	3478-12882	l33-491	473-1753	5461-20227	5765-21351

*   Increased cases of illness

See Appendix C for details of the calculations.

full wage rate of $8.10/hour for two days to arrive at an upper bound value of $129.56 per case and one-half the wage rate of $8.10/hour for one day to arrive at a lower bound value of $32.40 per case (1982$). These results are presented in Table 7-2. Since the cost of illness is not the same as the willingness to pay to avoid illness, these lost earnings represent a conservative proxy for the value of good health. Other factors might include a value for discomfort avoided and expenditures on medical care.

7.1.2 Benefit Estimates

The health benefits that are derived from cleaning up harbor waters are substantial for some parts of the Boston Harbor Study area and insignificant for others. The Wollaston and Quincy beaches show the greatest benefit because of the great number of beach visitors, the poor level of water quality, and the large percentage of predicted cleanup. Benefits for the Constitution and Dorchester Bay Beaches are not as great because, although water quality is often poor at the beaches, the water is not consistently dirty and, therefore, the greater number of cases of swimming-related gastroenteritis occur only sporadically. The benefits at Weymouth, Hingham, and Hull beaches are low because the water is relatively clean during most of the season, percent predicted cleanup is only 30 percent, and attendance figures are low compared to other Boston Harbor beaches.

7.1.3 Limits of Analysis

The key difficulties in accurately calculating health benefits are the water quality and population-at-risk data limitations, as well as the problems associated with valuing morbidity. Although we were able to develop

Table 7-2.   Swimming Health Benefits[a]
(1982 $000)

	CSO Option [b]	Ocean Outfall Option	Secondary Treatment Option	CSO Plus Ocean Outfall Option	CSO Plus Secondary Treatment Option
	$32.40-$129.56	$32.40-$129.56	$32.40-$129.56	$32.40-$129.56	$32.40-$129.5
Constitution	5.2-77.2	0.7-10.2	0.3-5.1	8.0-119.1	6.5-96.0
Dorchester Bay	21.3-316.7	2.3-33.1	2.3-33.1	32.2-477.3	32.2-477.3
Castle Island	0.7-10.0	0.1-0.9	0.1-0.9	0.9-13.3	0.9-13.3
Pleasure Bay	7.8-116.1	0.7-10.2	0.7-10.2	10.5-155.9	10.5-155.9
Carson	4.3-64.4	0.4-5.8	0.4-5.8	5.9-8 7.5	5.9-87.5
Malibu	6.4-95.2	0.6-8.8	0.6-8.8	9.2-136.8	9.2-136.8
Tenean	2.1-31.0	0.5-7.4	0.5-7.4	5.7-83.8	5.7-83.8
Wollaston	78.4-1161.0	9.5-140.6	9.5-140.6	134.3-1988.5	134.3-1988.5
Quincy	7.7-114.1	0.6-9.1	0.6-9.1	11.2-165.2	11.2-165.2
Weymouth	0	1.5-21.8	1.5-21.8	1.5-21.8	1.5-21.8
Hingham	0	0.3-4.5	0.3-4.5	0.3-4.5	0.3-4.5
Hull	0	0.9-13.0	0.9-13.0	0.9-13.0	0.9-13.0
Nantasket[c]	0	(11.3)- (168.7)	0	(11.3)- (168.7)	0
T O T A L	112.7-1,669.0	4.3-63.6	15.3-227.2	176.9-2,620.7	186.8-2,766.3

[a] Value per case of illness times number of cases from Table 7-1.

[b] $32.40 represents one day lost work at one-half wage rate and $129.56 represents two days lost work at full wage rate.

[c] Increased costs rather than savings.

a good statistical relationship between fecal coliform and _Enterococci_ because of available Boston data, in general such relationships are difficult if not impossible to determine because of variability in water quality conditions, which affect the survival patterns and relationships between various bacterial indicators in marine waters. Benefit estimates are also subject to bias because of assumptions made about water quality levels and swimming participation, because attendance figures only measure seasonal, and not yearly, beach visits because beach attendance may not reflect actual time spent in the water, and because the costs of illness do not include any measure of medical treatment.

In addition, estimating health benefits from swimming may be subject to double counting since swimmers may _perceive_ most of the health effects associated with water pollution. These benefits would thus be captured in whole or in part by the logit estimation, described in the previous Section of this report. More important than these limitations, however, is the fact that previously unavailable dose-response information can now be used to predict the number of swimming-related illnesses, provided towns and cities measure the appropriate indicator of bacterial contamination.

A note of caution is warranted in using the Cabelli _et al_. dose response function. This study is based on limited testing and the results have not been duplicated or verified by other studies.

7.2 Shellfish Consumption

Theoretically, health benefits resulting from improved water quality can be estimated by relating the reduction in frequency of water-related diseases to the reduced contamination of shellfish attributed to various levels of pollution abatement. Quantifying these benefits is difficult because of the

unavailability of a dose-response function for shellfish-borne diseases such'
as gastroenteritis, infectious hepatitis, and salmonellosis. Additional
difficulties are caused by the lack of information on the magnitude of
shellfish contamination and corresponding estimates of the population at
risk. Benefit estimation is further complicated by the difficulty in valuing
morbidity effects. Despite these methodological shortcomings, it is important
to attempt to estimate some of the shellfish-related benefits, if only to
illustrate that such techniques can be applied, given appropriate data.

It is possible to calculate benefits from reduction in incidence of
disease by applying assumed , rather than scientifically-derived, relationships
between water quality levels and incidence of disease. Assuming that disease
rates are proportional to the level of contamination, it is possible to
calculate a percentage reduction in the number of shellfish-borne cases of
disease based on a corresponding percentage cleanup. Almost one-half of the
shellfish acreage in Boston Harbor is classified as "grossly" contaminated and
is closed to harvesting because of potential health threats. It has been
estimated that, despite this closure, hundreds of bushels of contaminated
clams are being illegally harvested ("bootlegged") from these closed beds, and
sold on the open market. It is difficult to estimate the number of
contaminated clams that are reaching consumer tables, and even more difficult
to estimate what proportion of these clams can be linked to occurrence of
diseases. The only available indicator of shellfish-related diseases are the
actual reported outbreaks of gastroenteritis, hepatitis and other diseases.

In Boston, there have been few reported outbreaks of gastroenteritis or
other shellfish-related diseases. The Commonwealth of Massachusetts recorded
one outbreak of 30 cases of shellfish-related gastroenteritis in 1980. This
low disease rate does not necessarily indicate that there is little risk of

contracting shellfish-borne diseases or that shellfish contamination, due to polluted waters, does not exist. Rather, it suggests that a high proportion of cases are unreported, especially for the more common gastroenteritis cases. One study (Singley, et al., 1975) suggested that the ratio of actual to reported cases of foodborne diseases is 12:1. If this ratio were applied to the data from Boston, then we would expect a minimum of 360 cases per year of gastroenteritis due to shellfish contamination. Assuming a similar Scenario as described under swimming effects, these cases could be valued at a low of $32.40 and a high of $129.56. Potential damages would then range from $11,664 to $46,642.

It is not possible to relate reduction in water pollution, resulting from implementation of different pollution control plans, to corresponding reductions in incidence rate of these diseases and corresponding reductions in morbidity values because of the inadequate information relating a specific case to a specific shellfish area. It is important to note, however, that provided adequate data, the above technique can be applied, and corresponding benefits can be valued.

References

Cabelli, Victor J., et al., 1980.   Health Effects Quality Criteria for Marine
  Recreational Waters, Environmental Protection Agency, EPA-600/1-80-031.

Cabelli, V.J., A.P. Dufour, L.J. McCabe, and M.A. Levin. 1982. Swimming
  Associated Gastroenteritis and Water Quality. American Journal of
  Epidemiology, 115:606-616.

Meiscier, John J. and Victor J. Cabelli, 1982. Enterococci and Other
  Microbial Indicators in Municipal Wastewater Effluents, Journal of the Water
  Pollution Control Federation, Vol. 54, No. 12.

Singley, J. Edward et al., 1975, A Benefit/Cost Evaluation of Drinking Water
  Hygiene Programs, U.S. Environmental Protection Agency.

Section 8

Commercial Fisheries Benefits

Commercial fishing within Boston Harbor and the perimeter of Massachusetts Bay includes shellfishing, lobstering and finfishing. It is difficult to predict the precise impact of the various pollution abatement options because of lack of data on both productivity changes in relation to pollutant levels and current yields from the study area, especially for lobstering and finfishing. Because of differences in the available data, this section presents a general view of the potential impacts on lobsters and finfish and more detailed calculations for shellfishing.

As will be seen, the near-term benefits from reducing water pollution are modest. The most important factor affecting this lack of improvement is the problem of sediment contamination, which is affected by all sources of pollution (STPs, CSOs, non-point runoff, unauthorized site dumping, illegal discharges, and town sewers). The sediment throughout Boston Harbor is a sink for a number of toxic pollutants, particularly for heavy metals such as mercury, copper, nickel and silver, for PCBs, and for a number of pesticides, all of which are potentially detrimental to fish productivity and consumer health. There is scarce information about the precise levels of these contaminants in the sediment and even less information about their turnover and flushing rates. Added to this dilemma of sediment contamination is the problem of bacterial pollution from illegal dischargers, non-point sources and town sewers, all of which are difficult to locate, making it nearly impossible to precisely define their corresponding receptors. For these reasons, we have had to apply quite restrictive assumptions to the benefit calculations.

8.1 <u>Lobstering and Finfishing</u>

Lobstering is the most valuable fishery conducted within Massachusetts state waters. Total 1981 lobster landings were 9.5 million pounds and, at a value of $2.09 per pound, were worth $19.8 million.[a] Most of the lobstering activity occurs in Essex and Plymouth counties, along shoreline areas. Prior to 1979, the Massachusetts Division of Marine Fisheries did not keep data in a form which made it possible to determine amounts which were harvested in any particular area of the Harbor, Metcalf & Eddy (1982) have estimated that Dorchester Bay is the most productive area of the Harbor, followed in productivity by Quincy and Hingham Bays.[b] In 1979, however, the Division expanded the boundaries of the statistical catch area for lobster to include the entire Boston Harbor and portions of Massachusetts Bay out to a depth of 120 feet. Within this area, stretching from Lynn to Scituate and east past the Brewsters Islands, the total 1981 lobster catch was 2.6 million pounds worth $5.4 million if valued at $2.09 per pound, accounting for about 27 percent of total Massachusetts lobster supply.

Finfishing is also a commercial activity in Boston Harbor and the immediate Massachusetts Bay area. Boston is one of 51 commercial fishing harbors in Massachusetts, and in 1979 ranked third in Massachusetts in pounds of finfish landed. The approximately 57 gilt net line trawl vessels operating in and around the Harbor fish primarily for winter flounder, cod, and pollock, mostly during the summer months. There are also 29 draggers registered in Boston of which a small percentage fish within the Harbor area for menhaden and, just outside Boston Harbor, for winter flounder, yellow tail flounder, and cod. In addition, there are four seine boats which are known to fish the

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[a] Massachusetts Division of Marine Fisheries estimates.

[b] Lobster harvest was approximately 140,000 kg (308,000 lbs.) in Dorchester Bay in 1967 and 80,000 kg (176,000 lbs.) in Hingham Bay in 1970.

waters at the perimeter of Boston Harbor and Massachusetts Hay for sea herring. The National Marine Fisheries service records finfish landings in Boston Harbor but, unfortunately, these records do not include where the fish species are caught. For the year 1981, 28.4 million pounds of fish were landed in the port of Boston for a value of $12.4 million (National Marine Fisheries Service, 1983).

It is expected that reducing pollutant levels from the CSOs and the STPs will increase the productivity of lobstering and finfishing within the study areas but it is not possible to say by how much. On the other hand one treatment alternative, the deep ocean outfall option, will increase pollutant levels immediately surrounding the ocean diffuser in Masschusetts Bay. This option is expected to have an adverse impact on lobstering and finfishing activities in that area.

It is difficult to predict the precise impact that effluent from the ocean outfall discharge--which includes BOD, suspended solids, heavy metals and toxic chemicals--will have on the productivity of lobstering and finfishing because of insufficient dose-response data at sublethal concentrations and because of deficiencies in current knowledge of variations in ambient concentrations of water pollutants, which vary according to depth, current patterns, temperature conditions, tidal influences and estuarine influences. We must assume that pollution from ocean outfall effluent will have similar environmental effects as those reported for Boston Harbor, despite their biological, chemical and physical differences. Some information does exist, however, which enables us to predict the range of transport of some of the pollutants and the corresponding qualitative predicted impact of discharge on benthic fauna and commercial fisheries productivity.

Circulation in Massachusetts Bay (location of the ocean outfall) is not as efficient in terms of dispersion as are other area coastal locations, because the Bay is partially enclosed. Circulation is further restricted because of the depressed topographic features. The predicted ocean outfall discharge of 494,200 lbs/day of BOD and 369,000 lbs/day of suspended solids (including associated toxic pollutants such as PCBs, pesticides, and heavy metals) is expected to have an adverse effect on the biological population within the immediate discharge area and beyond the zone of initial dilution, although exact quantification of these effects is currently not possible. The discharge from the ocean diffuser is not expected to violate the Massachusetts' dissolved oxygen standard at the boundary of initial dilution, but it could be expected to violate the far-field and steady state benthic oxygen demand criteria due to abrupt resuspension.[a]

As stated in the waiver denial (US EPA, 1983) the proposed deep ocean outfall is expected to contribute nutrient stimulation of phytoplankton resulting in an adverse increase of pollution-tolerant phytoplankton and an increase in the amount of phytoplankton propagated at the existing site.[b] No measurable effects are expected for zooplankton-populations. The dilution dynamics at the proposed discharge site, the differences in the community structure of some of the populations, and the numerous near-shore pollution sources make it difficult to predict precisely the nature of the impact on biological community dynamics. In general, the proposed discharge is predicted to result in moderate, and possibly major, adverse impacts on the benthos. Major benthic alterations resulting from a sedimentation rate of 486 $g/m^2/yr$ would be expected to cover an area about 37 times the area of the

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[a] For a complete discussion of discharge and projected qualitative impacts, see US EPA, 1983.

[b] Based on observed impacts at present discharge areas in Boston Harbor, and a calculated deposition rate of sewage particles resulting in organic

zone of initial dilution (2.4 mi^2) whereas moderate impacts resulting from a sedimentation rate of 92 g/m^2/yr would extend over an area about 2,500 times that of the zone of initial dilution (166 mi^2) (US EPA, 1983; Tetra Tech, 1980).

The effects of these benthic changes on commercial fisheries are not immediately clear. In general, the reduction and changes in benthic fauna are expected to result in a decrease in available foods for finfish, crabs, and, to a lesser extent, lobsters over a 166 mi^2 area of Massachusetts Bay. Unfortunately, it is extremely difficult to quantify the exact magnitude of these effects on finfish and lobster productivity.

The part of this study area which is most likely to be affected by the proposed ocean outfall, and which also supports lobster populations, is the area of the Brewsters Islands on the perimeter of Boston Harbor and Massachusetts Bay. It is possible that an area of lobster exclusion may be formed around the Brewsters based on observed exclusions at the existing Lynn Wastewater discharge (Tetra Tech, 1982). This exclusion would result, however, in only a small reduction in total lobster catch. This is because the amount of lobster caught in the Brewster Islands area represents only a fraction of the over 2 million pounds of lobster harvested in the entire area (which extends from Lynn to Scituate, and includes inner Boston Harbor). Insufficient data on the number of pounds of lobster caught in this area prevents precise quantification of these effects.

Estimates of costs to commercial finfishery are equally difficult to determine. As was the case for lobsters, increased concentrations of pollutants are expected to detrimentally affect many of the fish populations. Fin erosion, particularly in winter flounder, is one of the few impacts which

are directly observable. Fin erosion has been detected in winter flounder

taken from inshore Harbor locations, although the exact cause of fin erosion

is not known. There is some evidence that fish develop the disease when

maintained in contact with contaminated sediments. There is also additional

evidence that PCBs may be involved in the development of the disease (US EPA,

1983; Sherwood, 1982). Based on this information, it is predicted that

finfish (particularly the winter flounder, which will be attracted to the

sediments because of their organic enrichment) will be affected by this

disease. Given the lack of information on how this disease specifically

alters species productivity and recruitment, however, it is currently not

possible to quantitatively estimate these effects on the economics of

commercial finfishing in the study area.

One final concern is the problem of toxic pollutants. Toxic pollutants

and pesticides can exert a number of adverse effects on marine organisms. The

ocean outfall option is expected to increase the concentrations of a number of

toxic pollutants in the ambient waters and sediments surrounding the ocean

outfall diffuser. Based on analysis by Tetra Tech (1980) and US EPA (1983),

it is predicted that copper, mercury, silver, and PCBs may exceed EPA water

quality criteria after initial dilution, unless alleviated by a toxic control

program. Although an initial dilution of 133:1 will help assure that metals

concentrations will fall below EPA water quality criteria, the unusually large

predicted volume of particulate matter and its associated toxic substances are

likely to result in high sediment concentrations of particulate-associated

toxicants which will adversely affect marine biota (US EPA, 1983). Lobsters

are particularly sensitive to copper concentrations; however, there is

uncertainty about the sublethal, chronic effects of this heavy metal on

lobster population dynamics. Even less is known about synergystic pollutant
effects on both finfish and lobster. [a]

Although toxic materials may be bioaccumulating in lobster and finfish
tissue and adversely affecting the dynamics of these populations, we must
conclude that because of insufficient biological, chemical and economic data,
the economic effects on these commercial fisheries must remain unquantified.

8.2 Commercial Shellfishing Industry

The shellfishing industry is the sector of commercial fishing to which the
greatest value could accrue from CSO or STP pollution abatement in Boston
Harbor. The soft shelled clam (Mya arenaria) is the most abundant
commercially valuable shellfish species found in Boston Harbor. Blue mussels
(Mytilus edulis) are also found but are not commercially valuable. The Boston
Harbor fishery is an important part of the Massachusetts shellfishing
industry; approximately twelve percent of the 1981 soft shelled clam harvest
came from the area. There are fifty-six shellfish areas in Boston Harbor
defined by the Massachusetts Division of Marine Fisheries, ranging in size
from one that is three acres in Weymouth to one of 400 acres in Hingham (see
Figure 8-1.). Total shellfish acreage is about 4,700 acres (see Table 8-1).
Almost one-half of this acreage (2,273) is classified as grossly contaminated
and, therefore, closed to harvesting. Slightly over one-half is classified as
moderately contaminated and is open to harvesting only by licensed master

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[a] Despite the fact that toxic pollutants are expected to adversely
affect the marine biota, bioaccumulation of these toxic chemicals are not
expected to exceed the FDA tolerance level for finfish and lobster (US EPA,
1983).

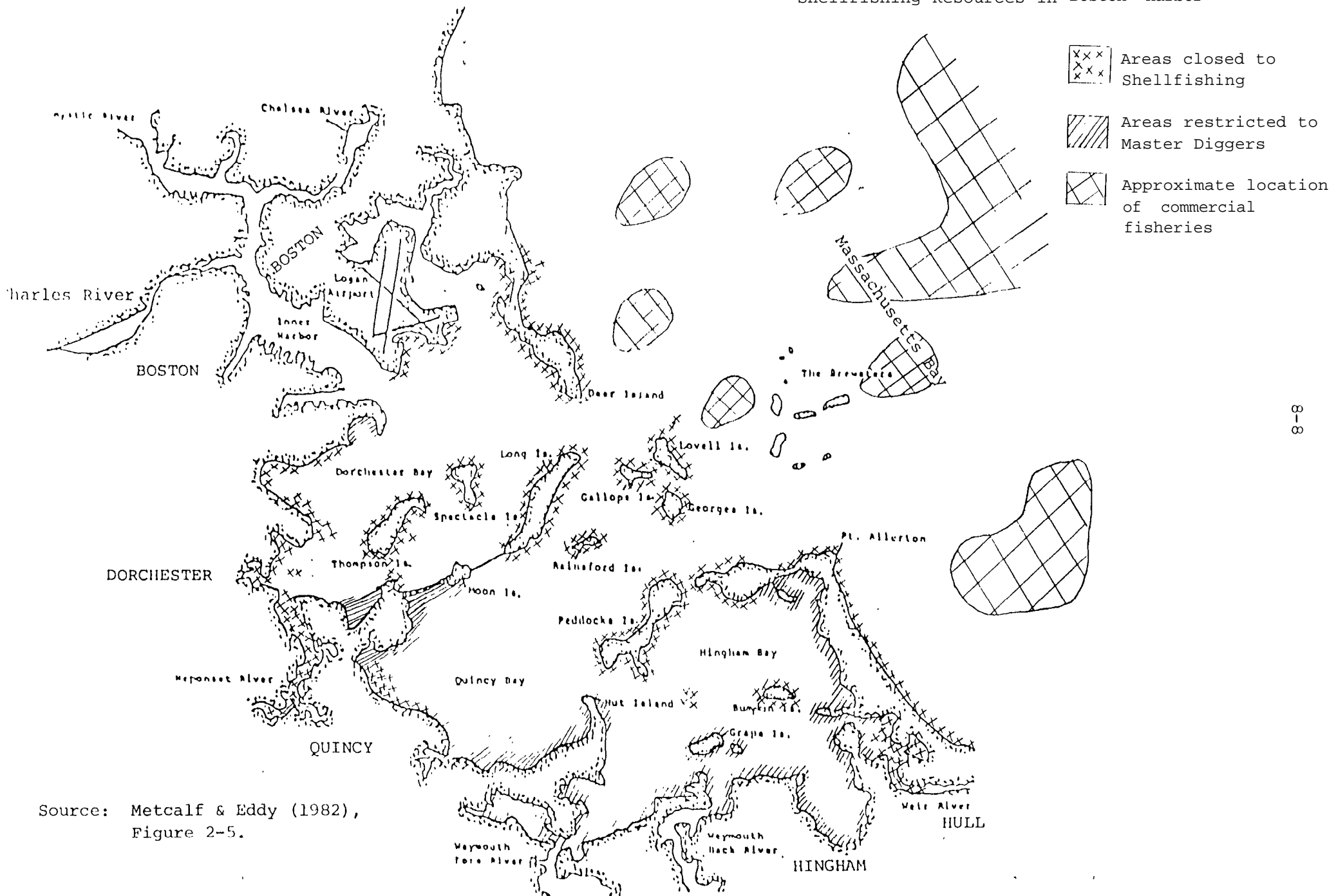Figure 8-1. Commercial Finishing and
Shellfishing Resources in Boston harbor

Areas closed to
Shellfishing

Areas restricted to
Master Diggers

Approximate location
of commercial
fisheries

Source: Metcalf & Eddy (1982),
Figure 2-5.

Table 8-1

Characteristics of Boston Harbor Shellfish Area&

Name of Adjacent City or Town or Land Area	Number of Shellfish Areas	Acreage by Classification[b]	
		Closed	Restricted
Constitution Beach Area	10	470	426
Winthrop	3	38	316
East Boston	7	432	110
Dorchester Bay Area	4	425	70
South Boston	2	125	40
Dorchester	2	300	30
Quincy	11	581	777
Weymouth	7	129	272
Hingham	3	37	464
Hull	8	172	344
Boston Harbor Islands:	13	689	105
Slate	1		30
Grape	1		55
Bumpkin	1		20
Georges	1	28	
Lovells	1	106	
Gallups	1	20	
Deer	1	18	
Long	1	106	
Spectacle	1	46	
Thompson	1	180	
Rainsford	1	37	
Sheep	1	la	
Peddocks	1	130	
TOTAL FLAT AREA	56	2,503	2,458
Estimated Productive Tidal Ar.a 2,300 acres		1,150	

a/ Department of Environmental Quality Engineering estimates.

b/ These acreages represent total flat area as opposed to tidal area. Productive acreage may be much smaller.

diggers and their employees. None of this area is open to unrestricted

digging. Special requirements such as the posting of a surety bond are placed

upon those who are issued master digger licenses by the state. Shellfish

from moderately contaminated areas must undergo depuration at the Shellfish

Purification Plant in Newburyport, Massachusetts, before being sold. The

Massachusetts shellfish sanitation program classifies shellfish areas by

standards developed by the U.S. Public Health Service and member states of the

Cooperative Program for Certification of Interstate Shellfish Shippers. Among

other criteria, areas are classified according to the MPN (mean probability

number) of total coliform bacteria per 100 ml of the overlying waters. Zero

to seventy MPN is defined as clean, seventy-one to seven hundred MPN is

defined as moderately contaminated (restricted) and above 700 is defined as

grossly contaminated (closed). Although bacterial quality of the water is one

criteria, the guidelines contain other requirements so that any potential

sources of pollution, direct or indirect, may be sufficient to declare an area

unfit even though bacterial limits were met.

8.2.1 Pollution Abatement Impacts

The implementation of CSO controls or STP improvements can be expected to

reduce the fecal and total coliform counts in the waters overlying the

shellfish areas in Boston Harbor, as discussed in the previous chapters.

Table 8-2 illustrates the changes that might occur in the classification of

shellfish bed acreage if the CSO and/or STP controls were implemented. The

anticipated changes would mean reclassification from grossly contaminated

(closed) to moderately contaminated (restricted), thereby allowing harvesting

Table 8-2. Estimated Potential Impacts of Pollution
Abatement Options on Boston Harbor Shellfish Areas a/

Adjacent Land Area	Potential Additional Acres Open to Restricted Harvesting due to Control Option b/				Optimum Annual Yield For Each Area (bu/acre) c/	Increased Yield Due to Control Option (bu/yr)			
	CSO			STP Ocean Outfall or Secondary Trmt.		CSO			STP Ocean Outfall or Secondary Trmt.
	Const.	Dorch/Nep.	Quincy			Const	Dorch./Nep.	Quincy	
Winthrop	5	--	--	14	50.0	250	--	--	700
East Boston	55	--	--	161	50.0	2,750	--	--	8,050
South Boston	--	16	--	--	62.5	--	1,000	--	--
Dorchester	--	75	--	--	50.0	--	3,750	--	--
Quincy d/	--	--	80	6	16.2	--	--	1,296	97
	--	--	20	1	50.0	--	--	1,000	50
Weymouth	--	--	--	6	50.0	--	--	--	300
Hingham	--	--	--	2	50.0	--	--	--	100
Hull	--	--	--	9	50.0	--	--	--	450
Boston Harbor Islands:	--	--	--	277	--	--	--	--	18,447
Long d/	--	--	--	56	35.7	--	--	--	1,999
	--	--	--	31	200.0	--	--	--	6,200
Spectacle	--	--	--	6	5.0	--	--	--	30
Thompson	--	--	--	180	55.6	--	--	--	10,008
Rainsford	--	--	--	1	60.0	--	--	--	60
Peddocks	--	--	--	3	50.0	--	--	--	150
TOTAL	60	91	100	476		3,000	4,750	2,296	28,194

Sources: Based on discussions with Department of Environmental Quality Engineering and Division of Marine Fisheries staff.

a/ These are general estimates; areas must be extensively surveyed and sampled prior to any actual reclassificaton.

b/ These acreages represent productive tidal areas. Where estimates of productive tidal area were unavailable, one-half of total flat area was used as an average figure.

c/ Where optimum yield data were unavailable, 50 bushels per acre was used as an average figure (see Harrington, no date).

d/ Two rows are used for these sites because they are composed of two parts with distinctly different optimum annual yields.

with depuration. It is not likely that areas now classified as restricted could be opened to unrestricted harvesting, due to such factors as sediment contamination which are unaffected by CSO controls or STP upgrading.

It should be noted that, while this analysis specifically looks at two main factors affecting the Boston Harbor shellfisheries' soft-shelled clams (CSOs and STP discharges), other factors will also have an impact (e.g., winter-kills on the clam beds and harbor maintenance through channel dredging). Also, as mentioned above , criteria other than bacterial levels are used to classify shellfish harvesting areas.

Based on information from the Massachusetts Department of Environmental Quality Engineering, about 725 acres could be reclassified if all pollution abatement options were implemented. This represents about 30 percent of the estimated total productive tidal area (as opposed to total flat area, see Tables 8-1 and 8-2) in the harbor and about 60 percent of the closed productive tidal area. The reclassification of acreage presented in Table 8-2 must be considered as only a general estimate. Areas would have to be surveyed and sampled extensively after implementation of any of the options before any reclassification could take place.

In order to determine the impact of the pollution abatement options on the shellfishing industry, it is necessary to translate the potential additional acreage open to restricted digging into an increased harvest which can be valued economically. To do this, an estimated optimum yield factor is used (see Table 8-2). The optimum yield is an estimate of the ideal annual level of harvest of a particular area which will maximize both present and future economic revenues derived from the fishery. It is based on the maximum

sustainable yield (MSY), which is a biologically determined level indicating the annual harvest rate at which the productivity of the resource is maximized. Any change from this level of fish catch, more or less, would result in a decrease in the equilibrium population of fish. Optimum yield differs from MSY in that it also accounts for fishing industry effort levels and benefits to society at large (see Pierce and Hughes, 1979). The optimum annual yield of a fishery is a function of costs and expected returns as well as the natural rate of growth of the fish population. It may be a different number than the MSY and, theoretically, allows for a profit-maximizing firm to deplete the resource. It is not expected that the pollution controls in question would lower the growth rate of shellfish in affected areas, so current optimum yields have been used here.

The production and yield of a shellfish resource is generally determined from a population density study of the area which place clams into class sizes seed, juveniles, intermediates and mature in the order of size groupings. These results afford information on the generation of yearly stock and of succeeding crop families. Data also is produced on the health of the shellfish, predation and a general distribution pattern of the shellfish in the area. The information on optimum yield in Table 7-2 was provided by the Massachusetts Department of Environmental Quality Engineering. Where no studies have been made an average figure of 50 bushels per acre was used.[a]

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[a] From Harrington (no date). Also, the Maine Department of Marine Resources rates acreage productivity for less than 25 bu/acres as poor, for 25-50 bu/acre as fair, for 50-75 bu/acre as good and for greater than 75 bu/acre as excellent (provided by E. Wong, environmental Protection Agency, Region I, Boston, MA).

Multiplying the optimum annual yield by the acreage potentially
reclassified due to each abatement option gives the increased annual yield
that could be realized, as shown in the last four columns of Table 8-2. The
economic benefits associated with these increased yields depend upon the
economics of the industry and the supply and demand for soft shelled clams, as
discussed below. It should be noted that compared with an estimated current
16,000 bushels annual yield in Boston Harbor, the maximum estimated increase
of 34,000 bushels from all pollution abatement options amounts to twice the
current annual yield. This potential increase would impact on the depuration
plant, patrol surveillances, and laboratory and water quality monitoring.
These factors could act to limit actual acreages opened to increased
harvesting.

8.2.2 Benefit Assessment Methodology

Two types of benefits--change in producer surplus and change in consumer
surplus--may be associated with an increased shellfish harvest resulting from
pollution abatement. Producer surplus is a measure of the well-being of a
firm and is defined as the excess of revenues over costs. Figure 8-2
ill&Gates typical, simplified demand (D) and supply (S_0) curves for the
shellfish industry. In the figure, producer surplus is the area below the
Price line (P_0) and above the supply curve (S_0); it is equal to the area
labeled "B" plus the area labeled "F". Consumer surplus is a measure of the
satisfaction a consumer derives from the purchase of goods and services and is
defined as the difference between what the individual is willing to pay and
what is actually paid. In Figure 8-2, consumer surplus is the area above the
Price line (P_0) and below the demand curve (D) (i.e., the area labeled "A").

Figure 8-2.

Typical Demand and Supply Curves for the Shellfish Industry
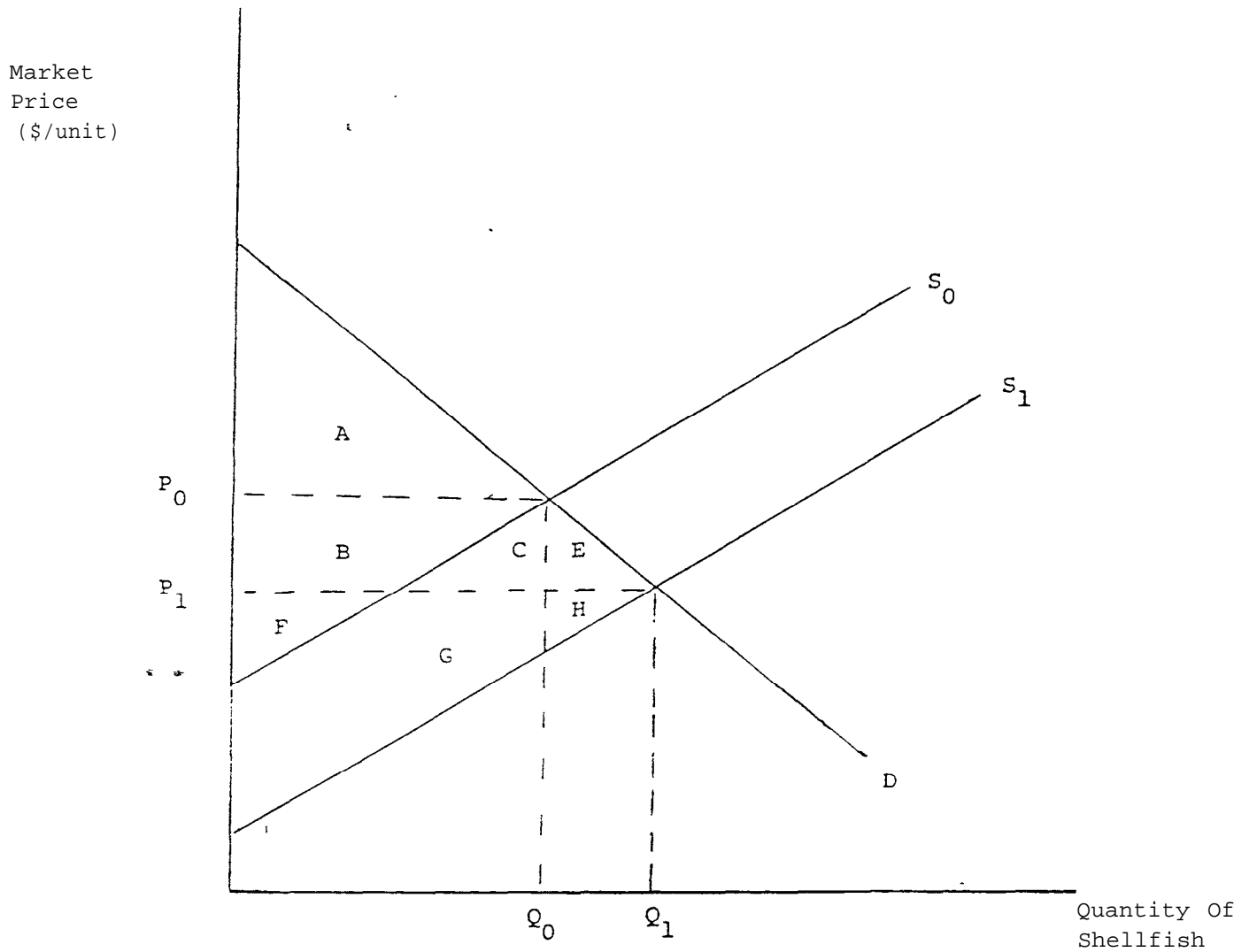
If the fishery is regulated and managed so that free entry by new firms is restricted, then a change in producer surplus may occur. If the increase in harvest is accompanied by either an unchanging price level or by a decrease in per unit harvest costs greater than the decrease in price, then increased profits will accrue to those firms in the restricted fishery throughout the time frame of the analysis. If entry is unrestricted, however, then the increased profits or rents to existing firms would be dissipated (after several years duration at best) as new firms are attracted to the industry, resulting in no long-run producer surplus.

A change in consumer surplus would depend upon a change in market price. If the increase in harvest is large relative to the total local market, then the market price could decrease, resulting in an increase in consumer surplus. If the increase in harvest is relatively small, or if the industry is oligopolistic (i.e., composed of only a few firms so that each can affect the whole industry) and the firms influence market price, then the price might not decline and no increase in consumer surplus would accrue.

Whether changes in either producer or consumer surpluses would result from the increased shellfish harvest estimated in the previous subsection for the pollution abatement options depends upon the shapes of the demand and supply curves for the industry. As mentioned above, in Figure 8-2 for price equals P_0 and quantity equals Q_0, consumer surplus is defined as the area A and producer surplus as the sum of the areas B + F. In the case illustrated, an increase in quantity to Q_1 along with a downward shift in the supply curve from S_0 to S_1, representing a decrease in per unit harvest costs (resulting from pollution abatement), results in a new lower equilibrium price, P_1. In this hypothetical example, both consumer and producer

surpluses are increased and these changes can be valued as economic benefits

associated with the pollution abatement, as follows:

```
Change  in  consumer  surplus  (CS)    =     New CS - Old CS
                                       =     ( A + B + C + E ) - A
                                       =     B + C + E

Change  in  producer  surplus  (PS)    =     New PS - Old PS
                                       =     (F + G + H) - (B + F)
                                       =     G + H - B .
```

These supply and demand curves must be estimated empirically for the

relevant benefits to be determined. For example, if the demand curve is very

elastic (i.e., flat) in the region of interest, then we can expect no

significant consumer surplus benefits to accompany an increase in quantity

produced. Broadly speaking, demand is elastic if quantity demanded is highly

responsive to price changes and is inelastic if it is not. A very elastic

demand curve would be one that is approaching a horizontal line and,

therefore, the change in consumer surplus (B + C + E in the above example)

would be very small. Or if, for instance, the supply curve for the industry

is not upward sloping in the region of concern, then no producer surplus would

be associated wth the production increase. Benefits estimated for a

particular fishery could include either consumer surplus benefits only or

producer surplus benefits only , or both types together, or no long-term

benefits, depending upon the shapes of the empirically estimated curves and

whether or not the fishery is regulated (i.e., entry restricted).

8.2.3 Benefit Estimates

Although the theory for estimating commercial fishing benefits is well

developed and straightforward, the application of that theory is difficult.

There are no readily available studies which define consumer demand or supply

curves for the soft shelled clam industry in Massachusetts or elsewhere.

Landings data (data on the quantity of shellfish harvested) are collected by the state but are felt to be reasonably accurate only for recent years. Exvessel price (price to the digger or firm) data are not available. The Boston area, however, is a major market for the industry. In 1980 consumption was estimated at approximately 625,000 bushels[a] Only 20 percent of that quantity was harvested in Massachusetts, about 125,000 bushels. About 20 to 25 percent was harvested in Maryland and the remainder in Maine. Maine and Maryland collect more extensive price and landings data than does Massachusetts.

A study was done in Maryland in the mid-1970s for various fisheries in the Chesapeake Bay, including the soft shelled clam fishery (Marasco, 1975). This study developed the following demand function for the soft shelled clam fishery, calibrated to late 1960s landings and price data in Maryland:

$$\log Q = 2.4606 - 2.3588 \log (P/CPI) + .6067 \log (I/CPI) \qquad R^2 = .91$$
$$\qquad\qquad (-9.5022)[b] \qquad\qquad\qquad (.9463)$$

where,

Q = landings in 1,000 lbs.
P = exvessel price in ¢/lb.
I = per capita income
CPI = consumer price index.

Price elasticity of demand is defined as the ratio of the relative change in quantity to the relative change in price, i.e., $(\Delta Q/Q)/(\Delta P/P)$. The price elasticity for clams in the above equation is -2.3588. Price elasticities for other species included in this study ranged from -.1 to -2. (See Appendix D.1 for a discussion of other demand curves investigated.)

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[a] Based on Division of Marine Fisheries estimates.
[b] Significant at the .01 level.

Unfortunately, the above demand function and other demand curves considered represent the total demand faced by the fishermen for their product which is shipped to more than one consumer market and not all consumed in Maryland. So the estimated price elasticity (-2.3588) cannot be automatically applied to develop a demand curve for Massachusetts consumers, even if the markets were assumed comparable. The price elasticity for Massachusetts consumers might be higher than the one in the above equation because many other fish species might be considered close substitutes. On the other hand, it has been said that demand for soft shelled clams in Massachusetts in the summer is unlimited; any that can be dug can be sold because of the high tourist demand for this well-known local specialty.

To account for the lack of data, consumer demand functions have been estimated for Massachusetts for a particular year (1981) for a range of price elasticities, from more elastic (-3) to less elastic (-.5) than the number in the above equation. Given the changes in yield estimated in the previous subsection for each pollution abatement option and given an estimated average price for that year (**\$31.41/bu[a/]**), new prices were estimated for each assumed price elasticity. The demand equation used is of the following form:

$$Q_{82} = A \times P_{82}^{\alpha} \text{ or,}$$

$$\log Q_{82} = \text{Log } A + \alpha \times \text{Log } P_{82}$$

[a/] Based on Resources for Cape Ann, 1982, price for 1980 (\$28.00) updated to 1982 price using soft shelled clams price index from National Marine Fisheries Service, NOAA, 1983.

where,

Q_{82} = quantity consumed in the Boston market in 1982
A   = constant
α = assumed price elasticity
P_{82} = average 1982 exvessel price for soft shelled clams in
       Massachusetts.

Table 8-3 displays the results of these estimates. The table shows that

as price elasticity increases (from -.5 to -3) and the demand curve becomes

flatter, the price changes resulting from the increases in clam harvest due to

the abatement options, decrease.   The price decrease is greatest for the

combined CSO and STP upgrade option with an inelastic demand curve assumed

(α = -.5).   The price change is least for the CSO options (taken separately)

with an elastic demand curve assumed (α = -3).

For reasons which are described below, it is likely that the primary

source of commercial fisheries benefits that would be associated with the

pollution abatement options would result from changes in consumer surplus

rather than producer surplus.   If no producer surplus changes occur (see

below), then total commercial fisheries benefits (equal to change in consumer

surplus) would be as shown in Table 8-4, following the same price elasticity

assumptions that were made for Table 8-3.

Consumer surplus benefits (Table 8-4) are estimated from the price changes

shown in Table 8-3 and from the changes in yields previously estimated for

each abatement option (see Table 8-2).   These changes in consumer surplus were

calculated from the following equation:

$$\Delta CS = \Delta P \times Q_0 + 1/2\ (\Delta P \times \Delta Q)$$

where,

ΔCS = change in consumer surplus (\$)
ΔP = change in price (\$)
Q_0 = initial consumption (bushels)
ΔQ = change in consumption (bushels).

Table 8-3.   Estimated Changes in Price of Soft Shelled
Clams Associated with Alternative Abatement Options
and with Assumed Price Elasticities of Demand (1982$)

Abatement Option		Elasticity (α)			
		-.5	-1	-2	-3
CSO					
Constitution	Price	31.11	31.26	31.33	31.36
	ΔP	-.30	-.15	-.08	-.05
Dorchester/Neponset	Price	30.94	31.17	31.29	31.33
	ΔP	-.47	-.24	-.12	-.08
Quincy	Price	31.18	31.30	31.35	31.37
	ΔP	-.23	-.11	-.06	-.04
Combined CSO[a]	Price	30.42	30.91	31.16	31.24
	ΔP	-.99	-.50	-.25	-.17
STP: Ocean Outfall	Price	28.76	30.05	30.72	30.95
or Secondary Treatment	ΔP	-2.65	-1.36	-.69	-.46
Combined CSO and STP[a]	Price	27.89	29.60	30.19	30.79
	ΔP	-3.52	-1.81	-.92	-.62

[a] All CSO options are combined in this row. Price changes are greater for
the combined plans than for the sum of the separate plans, because the demand
equation is not linear.

Table 8-4.   Estimated Total Benefits
Associated with Alternative Abatement Options
and with Assumed Price Elasticities of Demand (1982$)

Abatement Option	Elasticity (α)			
	-.5	-1	-2	-3
CSO				
Constitution	5,239	2,626	1,314	877
Dorchester/Neponset	8,674	4,353	2,181	1,455
Quincy	3,936	1,971	987	658
Combined CSO	20,727	10,446	5,243	3,501
STP: Ocean Outfall or Secondary Treatment	79,847	40,804	20,627	13,812
Combined CSO and STP	123,537	63,602	32,273	21,622

It was assumed that the harvest from Boston Harbor shellfish areas is consumed in the Boston area market. In addition, 16,000 bushels was used as a reasonable estimate of the annual harvest from Boston Harbor restricted areas before pollution abatement and, therefore, as the initial consumption estimate (Q_o)[a]. For a more detailed discussion of the computation methods used to obtain the new prices, price changes and consumer surplus benefits, see Appendix D.2.

As shown in Table 8-4, the total benefit levels vary in roughly the same way as the price changes shown in Table 8-3. This is because as the price decreases, the difference between price and willingness to pay increases, so that consumer surplus increases, and is shown by positive numbers in the table. The greatest benefits are obtained from the options with the greatest increase in yield and the most inelastic demand. Total benefits are larger for the combined options than for the sum of the separate options, because the demand equation is not linear.

It could also be legitimately argued that the change in consumer surplus could be zero. If all the pollution abatement options were implemented, then the increased harvest (34,000 bushels) would represent about six percent of the total market (625,000 bushels). Since it appears that none of the firms included in the Boston area market can influence price and since only a small percentage of them would be affected by the pollution abatement, it could be reasonably agreed that there would not be a change in consumer surplus given the small percentage increases in harvest just mentioned. Not enough is known about the consumer demand curve, however, to make a definitive judgment.

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[a] Division of Marine Fisheries

Thus from the considerations just discussed, we can conclude that the range of commercial fisheries benefits resulting from implementation of the pollution abatement options in Boston Harbor would be from zero to the higheststimates.levels presented in Table 8-4. The benefits estimates shown in Table 8-4, column 2 (price elasticity = -1) represent moderate levels between the upper and lower bounds just described.

As indicated above, no definitive estimates concerning producer surplus changes could be made due to lack of data. Attempts were made to develop a supply curve but were unsuccessful; these are described in Appendix D.3 along with an example showing how to compute change in producer surplus, if such benefits exist.

A reasonable argument can be made that the change in producer surplus would be zero for commercial shellfishing in Boston Harbor. This argument is that the supply curve is flat in the range of interest. If there is unlimited entry of firms into the fishery, then the additional profits or rents which would accrue to the master diggers currently operating in Boston Harbor restricted areas would be dissipated over the long run, leaving no long-term producer surplus benefits. There do exist institutional constraints on entry to the fishery; the State of Massachusetts places some restrictions upon master diggers allowed to operate in moderately contaminated areas: they must have a special license, post a surety bond, utilize specially licensed employees, meet certain transport requirements, keep certain records and are not allowed to concurrently harvest in areas classified as closed. There are no absolute restrictions to entry, however; as long as a firm meets the requirements, it may participate.[a]

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[a] For a discussion of various options for entry or effort regulation of New England fisheries, see Smith and Peterson, 1977.

In addition to the question of official restrictions on entry into the Boston Harbor shellfishing industry there is also evidence, as mentioned in the Section on Health Benefits, that thousands of bushels of contaminated clams are being bootlegged (illegally harvested) from the shellfish areas that are classified as closed by the state.[a/] This evidence shows that the official restrictions on Boston Harbor shellfishing are often ignored and that in practice there are few barriers to entry. It is, therefore, probable that the change in producer surplus that would result from the control options would only extend over a limited number of years until new firms attracted by the increased profits are able to meet the entry requirements. It is impossible to say how long these impediments would prevent new entries, but over the long term they may not keep the additional profits generated by the pollution abatement options from being reduced to zero.

8.2.4 Limits of Analysis

The major limitation of this analysis of commercial fisheries benefits is the lack of well-developed consumer demand and supply curves for the soft shelled clam industry. This makes application of the theory for estimating commercial benefits difficult. However, it is unlikely that a producer surplus exists and the true demand elasticity probably falls within the estimated demand elasticity range used in this study. Thus, the analysis was able to put bounds around the uncertainty.

Other data deficiencies include no good historical data for Massachusetts on harvest of soft shelled clams, numbers depurated and price to the digger. Little information also exists on the Boston consumer market and its sources and changes over time. Furthermore, there is only a small amount of data on

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[a/] Discussions with Division of Marine Fisheries staff and others.

costs of the firms in the industry, particularly those with special licenses

to operate in restricted areas. The impacts of pollution abatement and of

the resulting increase in yields on these costs are hard to judge, especially

the changes in numbers of employees and income to the master diggers. This

lack of data thus prevented a more precise estimation of shellfishing benefits.

References

Altobello, Marilyn A., David A. Storey and Jon M. Conrad, January 1977.
   The Atlantic Sea Scallop Fishery: A Descriptive and Econometric Analysis,
   Research Bulletin No. 643, Massachusetts Agricultural Experiment Station,
   University of Massachusetts, Boston, MA.

Arnold, David, January 31, 1983. Clammers Can't Work, Can't Get Benefits, The
   Boston Globe, Boston, MA.

Cape Cod Planning and Economic Development Commission, 1978. An Economic
   Profile of the Cape and Islands Fisheries.

Commonwealth of Massachusetts, Division of Marine Fisheries, 1981. Abstracts
   of Massachusetts Marine Fisheries Law, Boston, MA.

Commonwealth of Massachusetts, Division of Marine Fisheries, March 1982.
   Massachusetts Marine Fisheries Management Policy Report, Boston, MA.

Commonwealth of Massachusetts, Division of Marine Fisheries, 1982. Rules and
   Regulations Pertaining to the Issuance and Use of Master and Subordinate
   Digger Permits, Boston, MA.

Commonwealth of Massachusetts, Division of Marine Fisheries, 1982. Shellfish
   Areas Approved for Restricted Harvest with Depuration and Corresponding
   Routes to Newburyport Purification Plant, Boston, MA.

Crutchfield, Stephen R., February 1983. Soft Clam Exvessel Demand Functions
   and Clam Fishery Data, unpublished data, Department of Resource Economics,
   University of Rhode Island, Kingston, RI.

Dumanoski, Dianne, December 19 to 21, 1982. Boston's Open Sewer, three part
   series, The Boston Globe, Boston, MA.

Harrington, Peter, (no date). Shellfish Resource Estimates, unpublished memo,
   Massachusetts Department of Environmental Quality Engineering, Boston, MA.

Marasco, Richard J., May 1975, An Analysis of Future Demands, Supplies,
   Prices and Needs for Fishery Resources of the Chesapeake Bay, MP 868,
   Agricultural Experiment Station, University of Maryland, College Park,
   Maryland.

Marchesseault, Guy, Joseph Mueller, Lars Vidaeus and W.. Gail Willette, 1981.
   "Bio-Economic Simulation of the Atlantic Sea Scallop Fishery: A
   Preliminary Report, in K. Brian Haley (ed.), Applied Operations Research
   in Fishing, Plenum Publishing Corp., New York, NY.

Metcalf and Eddy, Inc., June 1982. Nut Island Wastewater Treatment Plant
   Facilities Planning Project, Phase I, Site Options Study, for the
   Metropolitan District Commission, Boston, MA.

National Marine Fisheries Service, NOAA, 1983. Fisheries of the U.S,
    Washington, DC.

National Marine Fisheries Service, NOAA, 1976. Fishery Statistics of the U.S,
    Washington, DC.

Pierce, David E. and Patricia E. Hughes, January 1979. Insight into the
    Methodology and Logic Behind National Marine Fisheries Services Fish
    Stock Assessments, Massachusetts Division of Marine Fisheries and Coastal
    Zone Management Office, Boston, MA.

Resources for Cape Ann, April 1982. The Costs of Pollution: The Shellfish
    Industry and the Effects of Coastal Water Pollution, Massachusetts Audubon
    Society.

Sherwood, M.J. 1982. Fin Erosion, Liver Condition, and Trace Contaminant
    Exposure in Fishes from Three Coastal Regions, In: "Ecological Stress
    and the New York Bight," Science and Management, pp. 359-377. Estuarine
    Research Federation, Columbia, South Carolina.

Smith, Leah J. and Susan B. Peterson, August 1977. The New England Fishing
    Industry: A Basis for Management, Technical Report WHOI-77-51, Woods Hole
    Oceanographic Institution, Woods Hole, MA.

Tetra Tech, Inc. 1980. Technical Evaluation of Deer Island and Nut Island
    Treatment Plants Section 301(h) Application for Modification of Secondary
    Treatment Requirements for Discharge into Marine Waters for U.S.
    Environmental Protection Agency.

Tetra Tech, Inc. 1981. Technical Evaluation of Lynn Wastewater Treatment
    Plant Section 301(h) Application for Modification of Secondary Treatment
    Requirements for Discharge into Marine Waters, for U.S. Environmental
    Protection Agency.

Townsend, Ralph and Hugh Briggs, September 1980. Some Estimates of Harvesting
    and Processing Costs for Maine's Marine Industries, technical report,
    Department of Economics, University of Maine.

U.S. Environmental Protection Agency, Economic Analysis Division, 1982. The
    Handbook of Benefit-Cost Assessment for Water Programs, Draft, Washington
    D.C.

U.S. Environmental Protection Agency, Office of Marine Discharge Evaluation,
    1983. Analysis of the Section 301(h) Secondary Treatment Waiver
    Application for Boston Metropolitan District Commission, Washington, D.C.

Wang, Der-Hsiung, Joel B. Dirlam and Virgil J. Norton, March 1978. Demand
    Analysis of Atlantic Groundfish, (preliminary report), Staff Paper No. 7,
    -Agricultural Experiment Station, University of Rhode Island, Kingston, RI.

Williams, Doug, (no date). Data and Procedures Used to Estimate Technical
    Coefficients for the Clam/Worm Sector, unpublished paper, Department of
    Agricultural and Resource Economics, University of Maine.